

13 CIV 1408

IN THE UNITED STATES DISTRICT COURT  
FOR THE SOUTHERN DISTRICT OF NEW YORK

MEDINOL LTD.,

*Plaintiff,*

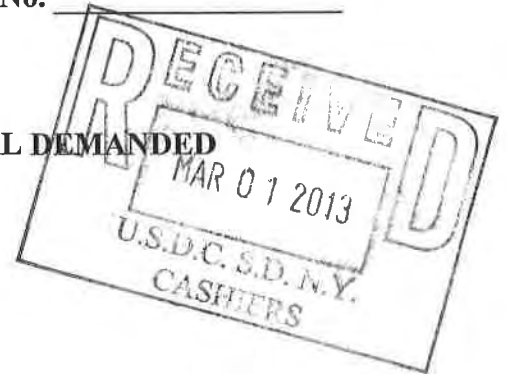
v.

CORDIS CORPORATION AND  
JOHNSON & JOHNSON,

*Defendants.*

Civil Action No. \_\_\_\_\_

JURY TRIAL DEMANDED



**COMPLAINT FOR PATENT INFRINGEMENT**

1. Plaintiff Medinol Ltd. ("Medinol" or "Plaintiff"), for its Complaint against Defendants Cordis Corporation ("Cordis") and Johnson & Johnson ("J&J") (collectively "Defendants"), upon knowledge as to its own acts and upon information and belief as to the acts of others, states and alleges as follows:

**THE PARTIES**

2. Plaintiff Medinol is an Israeli company with its principal place of business at Building #7, Entrance 1, 5th floor, Kiryat Atidim, Tel Aviv, 61581, Israel.

3. Upon information and belief, Defendant Cordis is a Florida corporation with its principal place of business at 430 Route 22 East, Bridgewater, New Jersey 08807.

4. Upon information and belief, Defendant J&J is a New Jersey corporation with its principal place of business at One Johnson & Johnson Plaza, New Brunswick, New Jersey 08933.

### **JURISDICTION AND VENUE**

5. This action arises under the patent laws of the United States, 35 U.S.C. § 1 *et seq.*, including 35 U.S.C. §§ 271, 281, 284, and 285. This Court has subject matter jurisdiction pursuant to 28 U.S.C. §§ 1331 and 1338(a).

6. Cordis and J&J are subject to personal jurisdiction in the State of New York and this District because, upon information and belief, they conduct business in this District and have committed acts of patent infringement in this District including, *inter alia*, offering for sale and/or selling infringing products, including at least the Cypher Stent, in this District. In addition, Cordis and J&J regularly place their products, including the Cypher Stent, within the stream of commerce, with the knowledge and/or understanding that such products will be sold in this District.

7. Venue is proper in this District pursuant to 28 U.S.C. §§ 1391(b), 1391(c) and/or 1400(b) because a substantial part of the events giving rise to Medinol's claims occurred in this District, Cordis and J&J are resident in or otherwise subject to personal jurisdiction in this District, and Cordis and J&J have committed acts of infringement in this District.

### **THE PATENTS-IN-SUIT**

8. Medinol owns all right, title and interest in U.S. Patent No. 5,980,552 (the "'552 patent"); U.S. Patent No. 6,059,811 (the "'811 patent"); U.S. Patent No. 6,589,276 (the "'276 patent"); and U.S. Patent No. 6,875,228 (the "'228 patent") (collectively, the "patents-in-suit").

9. The '552 patent, entitled "Articulated Stent," was duly and legally issued by the United States Patent and Trademark Office on November 9, 1999. A true and correct copy of the '552 patent is attached hereto as Exhibit A.

10. The '811 patent, entitled "Articulated Stent," was duly and legally issued by the United States Patent and Trademark Office on May 9, 2000. A true and correct copy of the '811 patent is attached hereto as Exhibit B.

11. The '276 patent, entitled "Articulated Stent," was duly and legally issued by the United States Patent and Trademark Office on July 8, 2003. A true and correct copy of the '276 patent is attached hereto as Exhibit C.

12. The '228 patent, entitled "Articulated Stent," was duly and legally issued by the United States Patent and Trademark Office on April 5, 2005. A true and correct copy of the '228 patent is attached hereto as Exhibit D.

13. Each of the four patents-in-suit claims priority to U.S. Application No. 08/213,272 (the "'272 application"), filed on March 17, 1994, which issued as U.S. Patent No. 5,449,373 (the "'373 patent") on September 12, 1995.

14. Upon information and belief, Cordis and J&J had knowledge of the '373 patent no later than when the '373 patent issued in 1995, and knowledge of the continuation applications that claim priority to the '373 patent and that led to the patents-in-suit on or about the time the applications were pending and publicly available for inspection in the United States Patent and Trademark Office. Upon information and belief, Cordis and J&J had knowledge of each of the patents-in-suit on or about the date each patent issued, but in no event later than 2006.

15. In an earlier case in this District before District Judge Scheindlin captioned as *Medinol Ltd. v. Guidant Corp. and Advanced Cardiovascular Systems, Inc.*, No. 03 Civ. 2604, Medinol asserted different but related patents that issued from a continuation-in-part application of the '272 application that is the parent application of the '552, '811, '276 and '228 patents. In the course of construing the patent claim language and ruling on motions for summary judgment

related to validity and other issues in the Guidant case, Judge Scheindlin considered the prosecution history of the '272 parent application, as well as certain prior art references that may also be relevant in this new case. *See, e.g., Medinol Ltd. v. Guidant Corp.*, 341 F.Supp.2d 301 (S.D.N.Y. 2004); *Medinol Ltd. v. Guidant Corp.*, 2004 WL 2210290 (S.D.N.Y. Sept. 30, 2004); *Medinol Ltd. v. Guidant Corp.*, 412 F.Supp.2d 301 (S.D.N.Y. 2005); *Medinol Ltd. v. Guidant Corp.*, 417 F.Supp.2d 280 (S.D.N.Y. 2006).

## COUNT I

### INFRINGEMENT OF THE '552 PATENT

16. Medinol incorporates each of the preceding paragraphs 1-15 as if fully set forth herein.

17. Cordis and J&J have directly infringed the '552 patent, in violation of 35 U.S.C. § 271(a), by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that embody the patented invention, including the Cypher Stent and the Cypher Select Stent.

18. Upon information and belief, Cordis and J&J's infringement of the '552 patent has been and is willful because Cordis and J&J have had knowledge of the '552 patent since on or about the date the '552 patent issued, November 9, 1999, but have nonetheless deliberately engaged in infringing conduct by making, using, selling, offering for sale, and/or importing the Cypher Stent and the Cypher Select Stent despite knowing that these products infringe the '552 patent.

19. As a direct and proximate result of the acts of patent infringement by Cordis and J&J, Medinol has been damaged and is entitled to damages in an amount adequate to compensate Medinol for this infringement of the '552 patent, but in no event less than a reasonable royalty

under 35 U.S.C. § 284.

20. Medinol has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and Medinol is entitled to recover its reasonable and necessary fees and expenses.

## **COUNT II**

### **INFRINGEMENT OF THE '811 PATENT**

21. Medinol incorporates each of the preceding paragraphs 1-15 as if fully set forth herein.

22. Cordis and J&J have directly infringed the '811 patent, in violation of 35 U.S.C. § 271(a), by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that embody the patented invention, including the Cypher Stent and the Cypher Select Stent.

23. Upon information and belief, Cordis and J&J's infringement of the '811 patent has been and is willful because Cordis and J&J have had knowledge of the '811 patent since on or about the date the '811 patent issued, May 9, 2000, but have nonetheless deliberately engaged in infringing conduct by making, using, selling, offering for sale, and/or importing the Cypher Stent and the Cypher Select Stent despite knowing that these products infringe the '811 patent.

24. As a direct and proximate result of the acts of patent infringement by Cordis and J&J, Medinol has been damaged and is entitled to damages in an amount adequate to compensate Medinol for this infringement of the '811 patent, but in no event less than a reasonable royalty under 35 U.S.C. § 284.

25. Medinol has incurred and will incur attorneys' fees, costs, and expenses in the

prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and Medinol is entitled to recover its reasonable and necessary fees and expenses.

### **COUNT III**

#### **INFRINGEMENT OF THE '276 PATENT**

26. Medinol incorporates each of the preceding paragraphs 1-15 as if fully set forth herein.

27. Cordis and J&J have directly infringed the '276 patent, in violation of 35 U.S.C. § 271(a), by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that embody the patented invention, including the Cypher Stent.

28. Upon information and belief, Cordis and J&J's infringement of the '276 patent has been and is willful because Cordis and J&J have had knowledge of the '276 patent since on or about the date the '276 patent issued, July 8, 2003, but have nonetheless deliberately engaged in infringing conduct by making, using, selling, offering for sale, and/or importing the Cypher Stent despite knowing that these products infringe the '276 patent.

29. As a direct and proximate result of the acts of patent infringement by Cordis and J&J, Medinol has been damaged and is entitled to damages in an amount adequate to compensate Medinol for this infringement of the '276 patent, but in no event less than a reasonable royalty under 35 U.S.C. § 284.

30. Medinol has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and Medinol is entitled to recover its reasonable and necessary fees and expenses.

## **COUNT IV**

### **INFRINGEMENT OF THE '228 PATENT**

31. Medinol incorporates each of the preceding paragraphs 1-15 as if fully set forth herein.

32. Cordis and J&J have directly infringed the '228 patent, in violation of 35 U.S.C. § 271(a), by making, using, selling, offering for sale, and/or importing in or into the United States, without authority, products that embody the patented invention, including the Cypher Stent.

33. Upon information and belief, Cordis and J&J's infringement of the '228 patent has been and is willful because Cordis and J&J have had knowledge of the '228 patent since on or about the date the '228 patent issued, April 5, 2005, but have nonetheless deliberately engaged in infringing conduct by making, using, selling, offering for sale, and/or importing the Cypher Stent despite knowing that these products infringe the '228 patent.

34. As a direct and proximate result of the acts of patent infringement by Cordis and J&J, Medinol has been damaged and is entitled to damages in an amount adequate to compensate Medinol for infringement of the '228 patent, but in no event less than a reasonable royalty under 35 U.S.C. § 284.

35. Medinol has incurred and will incur attorneys' fees, costs, and expenses in the prosecution of this action. The circumstances of this dispute create an exceptional case within the meaning of 35 U.S.C. § 285, and Medinol is entitled to recover its reasonable and necessary fees and expenses.

### **PRAYER FOR RELIEF**

Medinol requests that judgment be entered in its favor and against Cordis and J&J, and that the Court award the following relief to Medinol:



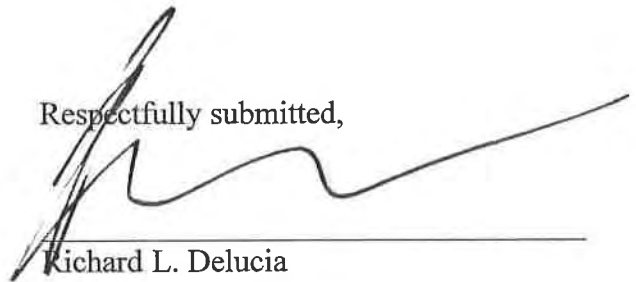
- (a) damages in an amount adequate to compensate Medinol for infringement of the patents-in-suit, and in no event less than a reasonable royalty;
- (b) increased damages in an amount three times the damages found by the jury or assessed by the Court for the willful infringement of the patents-in-suit pursuant to 35 U.S.C. § 284;
- (c) expenses, costs, and reasonable attorneys' fees pursuant to 35 U.S.C. § 285 and Federal Rule of Civil Procedure 54;
- (d) prejudgment and post-judgment interest on all damages; and
- (e) such other and further relief as the Court deems just and proper.

**JURY DEMAND**

In accordance with Federal Rules of Civil Procedure 38 and 39, Medinol asserts its rights under the Seventh Amendment to the United States Constitution and demands a trial by jury on all issues triable by a jury.

Dated: March 1, 2013

Respectfully submitted,



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## **EXHIBIT A**



US005980552A

**United States Patent** [19]**Pinchasik et al.**[11] **Patent Number:** **5,980,552**[45] **Date of Patent:** **\*Nov. 9, 1999**[54] **ARTICULATED STENT**[75] **Inventors:** **Gregory Pinchasik; Jacob Richter,**  
both of Ramat Hasharon, Israel[73] **Assignee:** **Medinol Ltd., Tel Aviv, Israel**[\*] **Notice:** This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

This patent is subject to a terminal disclaimer.

[21] **Appl. No.:** **08/760,359**[22] **Filed:** **Dec. 4, 1996****Related U.S. Application Data**

[63] Continuation of application No. 08/455,462, May 31, 1995, abandoned, which is a continuation of application No. 08/213,272, Mar. 17, 1994, Pat. No. 5,449,373.

[51] **Int. Cl.<sup>5</sup>** ..... **A61M 5/00**[52] **U.S. Cl.** ..... **606/198; 623/1; 623/12**[58] **Field of Search** ..... **606/1, 108, 191,**  
**606/194, 195, 198, 200; 623/1, 11, 12;**  
**128/898, 899**[56] **References Cited****U.S. PATENT DOCUMENTS**

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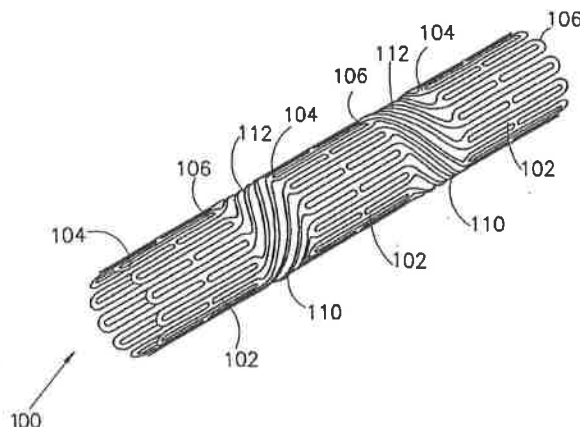
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*Primary Examiner*—Michael Buiz*Assistant Examiner*—William Lewis*Attorney, Agent, or Firm*—Kenyon & Kenyon[57] **ABSTRACT**

An articulated stent for delivering through a bodily conduit, for example, a peripheral or coronary artery, which has one or more curved portions and for implantation therein. The articulated stent includes at least two substantially rigid segments and a flexible connector for connecting adjacent segments. The connector assumes a cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

**14 Claims, 5 Drawing Sheets**

U.S. Patent

Nov. 9, 1999

Sheet 1 of 5

5,980,552

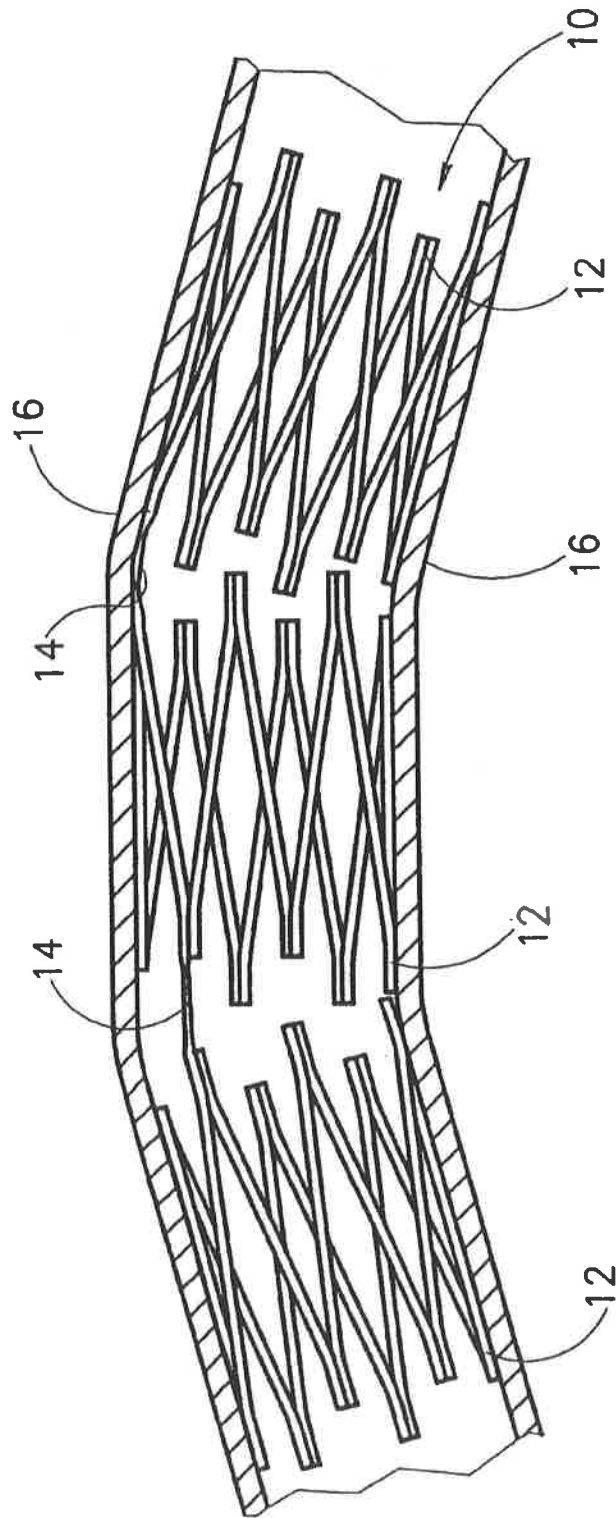


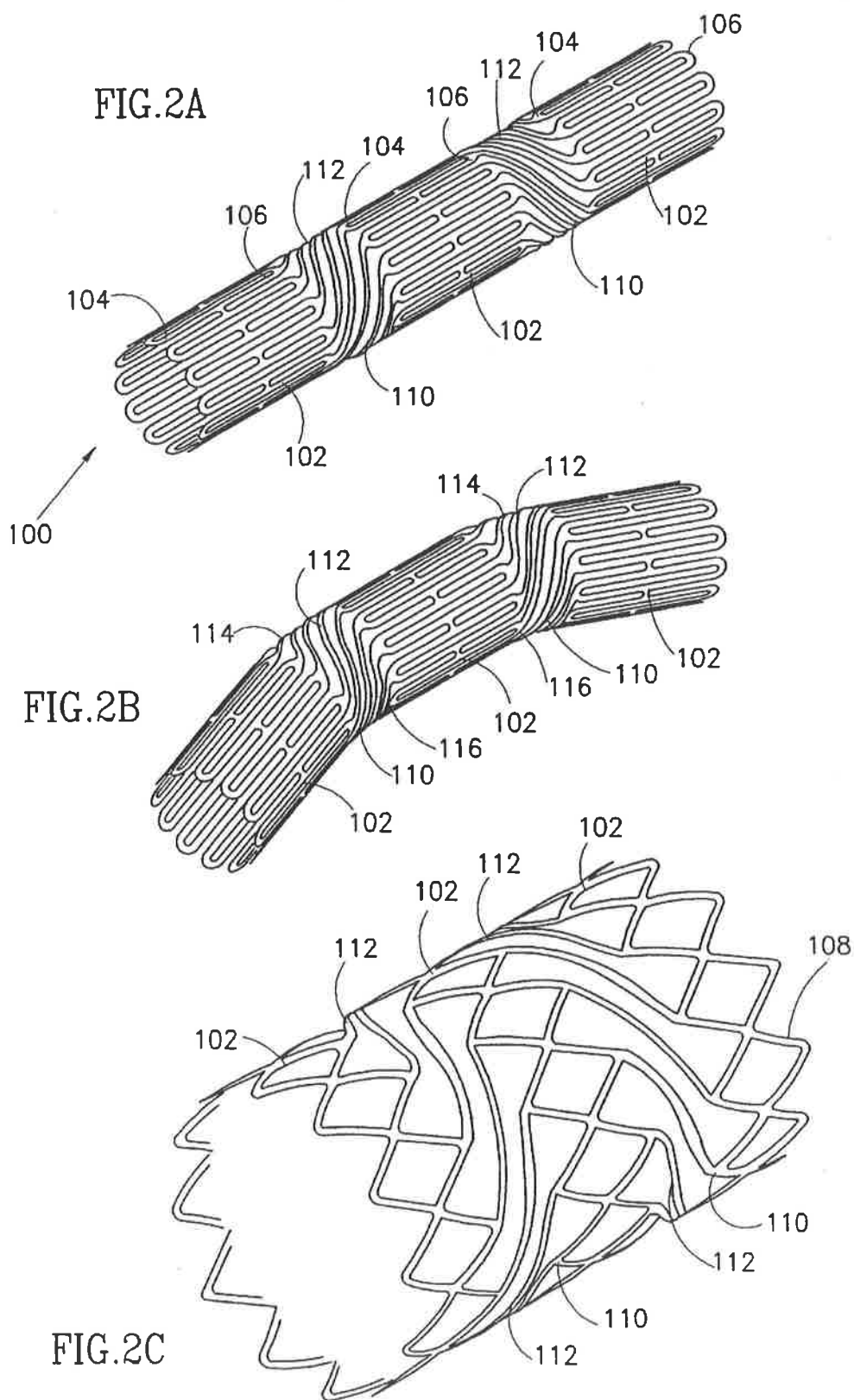
FIG. 1  
PRIOR ART

U.S. Patent

Nov. 9, 1999

Sheet 2 of 5

5,980,552

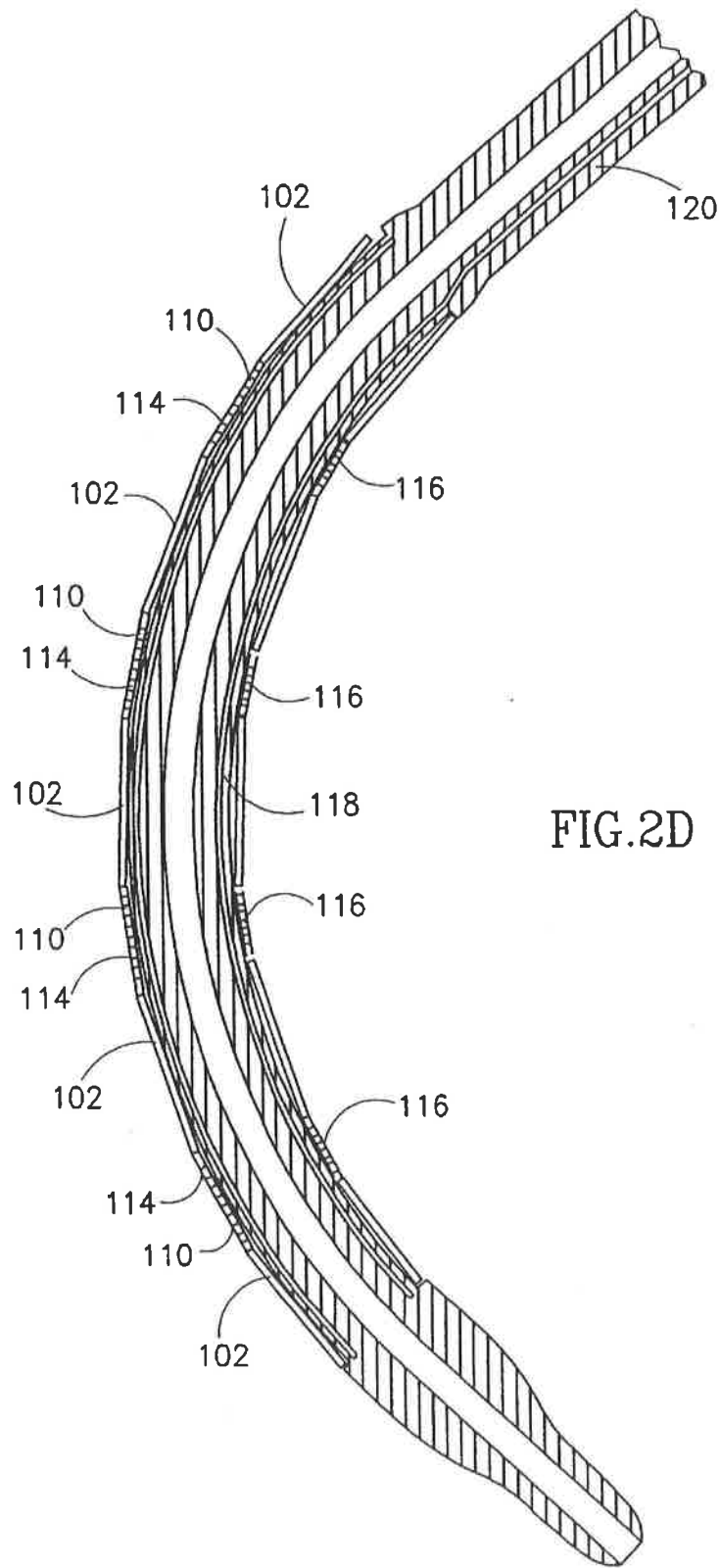


U.S. Patent

Nov. 9, 1999

Sheet 3 of 5

5,980,552



U.S. Patent

Nov. 9, 1999

Sheet 4 of 5

5,980,552

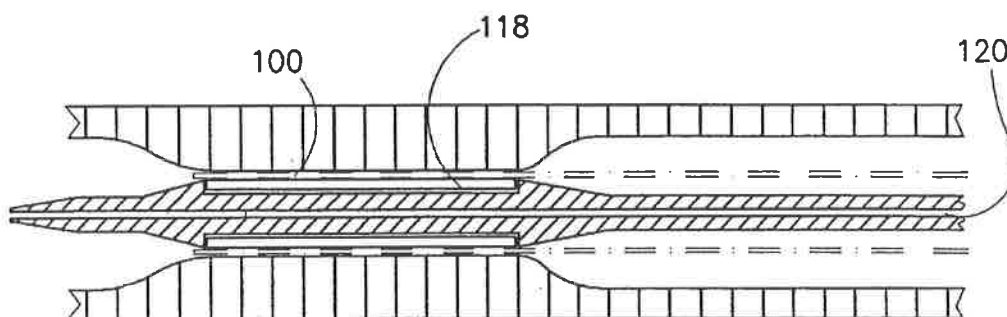


FIG. 2E

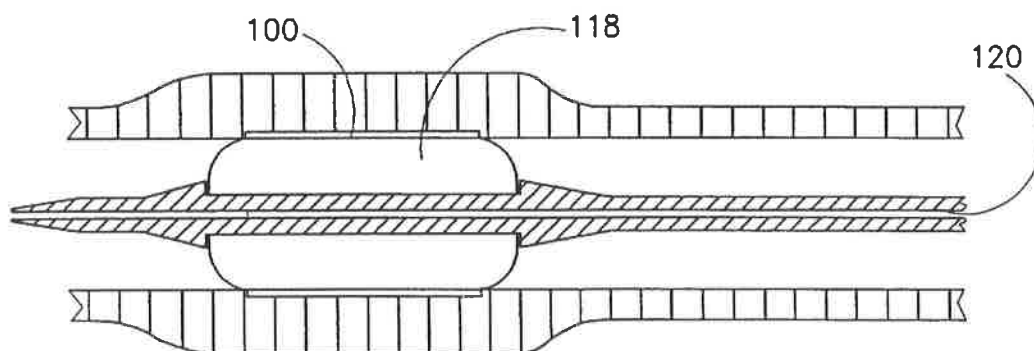


FIG. 2F



U.S. Patent

Nov. 9, 1999

Sheet 5 of 5

5,980,552

FIG. 3A

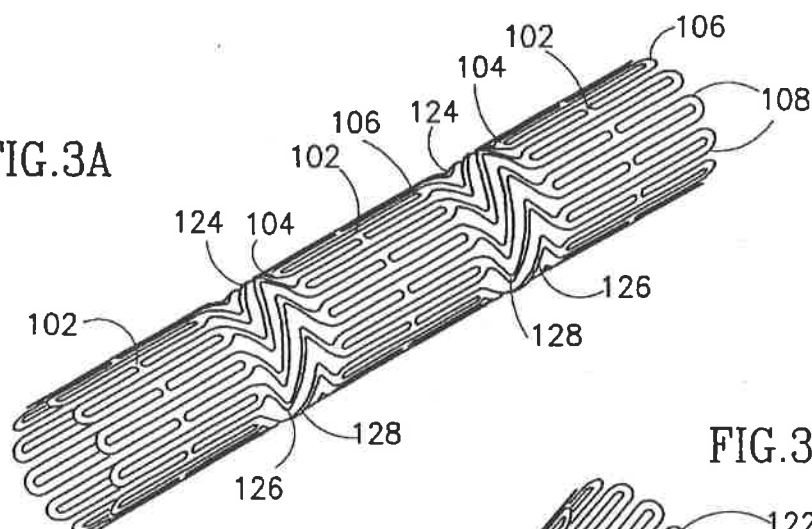


FIG. 3B

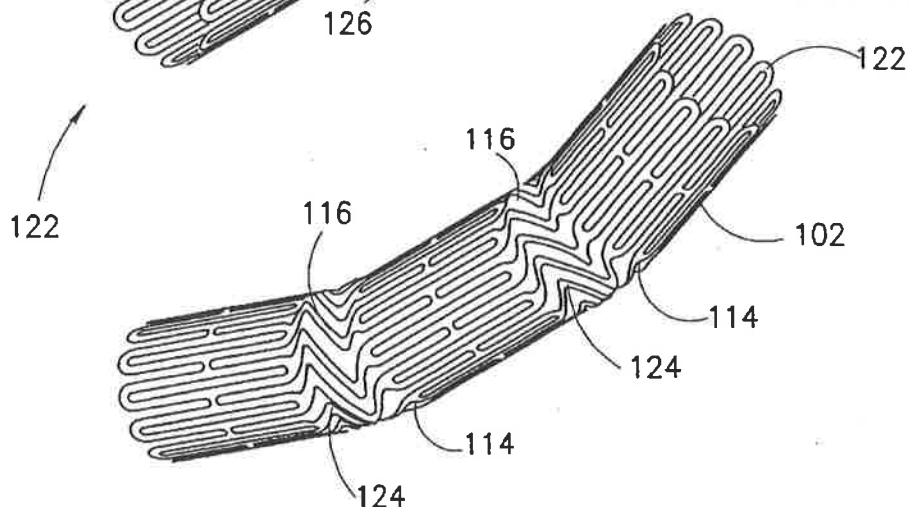
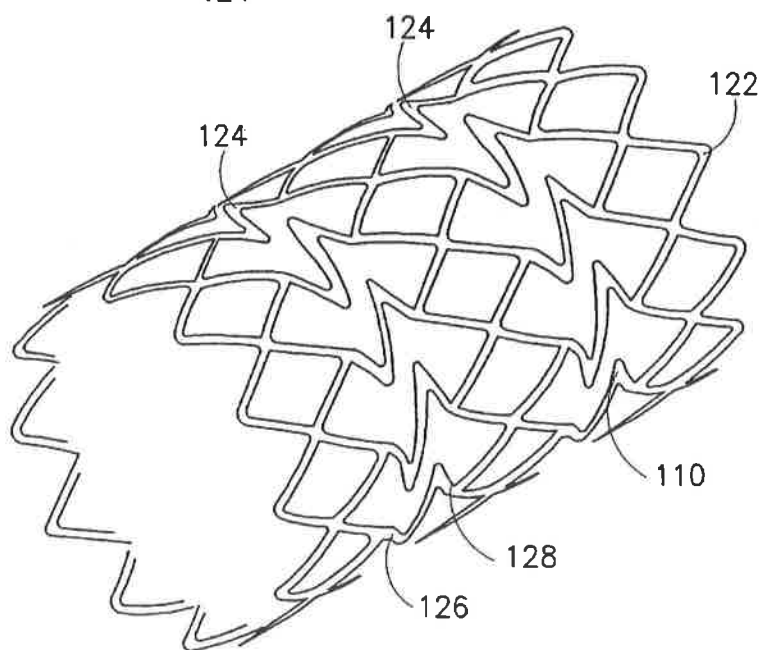


FIG. 3C





5,980,552

## 1 ARTICULATED STENT

This application is a continuation of application Ser. No. 08/455,462, filed on May 31, 1995, now abandoned, which is a continuation of Ser. No. 08/213,272 filed Mar. 17, 1994 now U.S. Pat. No. 5,449,373.

### FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to stents which are implanted as part of a balloon angioplasty procedure within a bodily conduit of a living animal or a human to maintain patency. In particular, the present invention relates to articulated intravascular stents for delivery through or implantation in a blood vessel having a curved portion.

Intravascular stents having a constricted diameter for delivery through a blood vessel and an expanded diameter for applying a radially outwardly extending force for supporting the blood vessel are known in the art. Articulated intravascular stents for either delivery through a curved blood vessel or implanted therein are also known in the art.

Self-expandable articulated stents are described, for example, in U.S. Pat. No. 5,104,404 entitled "Articulated Stent" to Wolff. Balloon expandable articulated stents are commercially available under the trade name Palmaz-Schatz Balloon-Expandable Stents from Johnson & Johnson Intervention Systems Co.

A prior art self-expandable articulated intravascular stent 10 deployed in a curved blood vessel 16 is now described with reference to FIG. 1 which is, in actual fact, FIG. 2 of the above referenced U.S. Pat. No. 5,104,404. Stent 10 is made up of a number of individual segments 12 articulated by hinges 14 connected at each end to segments 12. Stent 10 is preferably fabricated from memory shape material, for example, nitinol, and as such is self expandable after delivery from a delivery system described in U.S. Pat. No. 4,830,003 to Wolff et al. However, these prior art articulated intravascular stents suffer from a number of disadvantages both during delivery through a curved blood vessel and when implanted therein as will now be described.

The delivery of stent 10 through curved blood vessel 16 is more complicated than the delivery of a non-articulated stent in that stent 10 has to be angularly oriented such that its hinges 14 are located towards the convex portion of blood vessel 16 so that stent 10 can be flexed inward. In the present example, it will be noted that hinges 14 are located on the same side of segments 12 because blood vessel 16 has only a simple curve in one plane. It can be readily appreciated that delivery of stents through blood vessels which have one or more curved portions which are not in the same plane is even more complicated and generally requires specially constructed stents.

Even when implanted in a curved blood vessel 16, stents 10 are shown to be lacking in that the gaps between segments 12 render the curved portion of blood vessel 16 without support. Furthermore, the gaps at the convex portion of blood vessel 16 are substantially greater than the gaps at the concave portion thereof, thereby inducing non-uniform and therefore undesirable stresses on blood vessel 16.

Therefore, it would be highly desirable to have an articulated stent which does not require any particular angular orientation when being delivered through a curved bodily conduit and provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted.

It would also be highly desirable the structure of a stent does not depend on the particular orientations of curved portions of a blood vessel.

## 2 SUMMARY OF THE INVENTION

The object of the present invention is for an articulated stent which can be delivered through a curved bodily conduit using a routine medical procedure and a conventional stent delivery system. Furthermore, the stent provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted. Still further, the structure of a stent and its support of a bodily conduit do not depend on the orientations of the curved portions of the conduit.

The objective of the present invention is achieved by an articulated stent, comprising: (a) at least two substantially rigid segments; and (b) a flexible connector for connecting adjacent segments, wherein the connector assumes a substantially cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

After expansion, the rigid segments of the stent preferably present a fine diamond shaped mesh having 1 mm long sides to provide continuous and uniform support for straight portions of a bodily conduit.

The connectors can be implemented as a plurality of substantially helical links connecting adjacent segments. Alternatively, the connectors can be implemented as links each having at least one kink. The connectors typically have between 8-24 links to provide continuous and uniform support for both straight and curved portions of a bodily conduit.

The stents have constricted diameters for intraluminal delivery and are then deformed, by the inflation of a balloon forming part of their catheter delivery system, to expanded diameters for applying radially outwardly extending forces for supporting the lumen of bodily conduits. The constricted and expanded diameters of the stents typically fall in the ranges of 1.0-3.5 mm and 3.5-10.0 mm, respectively.

The stents are preferably fabricated from low memory, more plastic than elastic, bio-compatible materials, for example, stainless steel 316L, gold, tantalum, etc. which enables them to be plastically deformed from their constricted diameters to their expanded diameters.

A typical stent for implantation in a human coronary artery is 9-21 mm long comprising three to seven 2.2 mm long stent segments connected by two to six 1 mm long connectors such that the ends of the stent subtend between a 45° to 135° angle at a radius of curvature of approximately 9 mm when flexed.

### BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 shows a close-up view of a prior art articulated stent of deployed in a curved blood vessel;

FIGS. 2a and 2b show a preferred embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation;

FIG. 2c shows the expanded stent of FIG. 2 after plastic deformation;

FIG. 2d shows the stent of FIG. 2 mounted on a catheter in its flexed state;

FIGS. 2e and 2f show the stent of FIG. 2 before and after expansion by a balloon forming part of its catheter delivery system;

5,980,552

3

FIGS. 3a and 3b show a second embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation; and

FIG. 3c shows the expanded stent of FIG. 3 after plastic deformation.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of an articulated stent for delivering through a curved bodily conduit, for example, a peripheral or coronary artery of a living animal or a human and implantation therein as part of a balloon angioplasty procedure to maintain patency.

The principles and operation of the articulated stent of the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, FIGS. 2a-2c show an articulated stent, generally designated 100, constructed and operative according to the teachings of the present invention, generally comprising a number of substantially rigid segments 102 connected by connectors 110.

Segments 102 are preferably made up to present a fine diamond mesh of interconnected diamond shaped cells 108 having 1 mm sides on expansion as best seen in FIG. 2c. Depending on the intended diameter of stent 100, segments 102 typically comprise between 8-24 diamond shaped cells 108.

Connectors 110 comprise links 112 connecting a front end 104 to a tail end 106 of adjacent segments 102. Links 112 preferably extend in a substantially helical fashion between apexes of diamond shaped cells 108 at front and rear ends 104 and 106 of adjacent segments 102 such that the number of links 112 equals the number of cells 108. Links 112 are preferably evenly deployed around perimeters of segments 102 such that connectors 110 can be equally flexed in any direction and to provide continuous and uniform support to both straight and curved portions of a bodily conduit.

Alternate connectors 110 at front and rear ends 104 and 106, respectively, of a segment 102 preferably have links 112 wound in clockwise and counter clockwise directions. Alternately winding connectors 110 ensures that the rotational displacement of links 112 and adjacent segments 102 relative to the walls of a blood vessel and more importantly the balloon of its delivery system is minimized when stent 100 is expanded.

It is particular feature of the present invention that connectors 110 have a generally cylindrical configuration when stent 100 is relaxed as best seen in FIG. 2a and a differentially stretched and compressed curved configuration when stent 100 is flexed as best seen in FIG. 2b. The flexed configuration is brought about by two relatively opposing displacements of links 112. First, the differential stretching of connectors 110 occurs at the convex portion thereof denoted 114 by links 112 being displaced away from one another. Second, the differential compressing of connectors 110 occurs at the concave portion thereof denoted 116 by links 112 being displaced towards one another.

Stent 100 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 2a and 2b and an expanded diameter as shown in FIG. 2c for supporting a bodily conduit. Stent 100 is preferably fabricated from low memory, more plastic than elastic, biocompatible material, for example, stainless steel 316L, gold, tantalum, etc. which enables it to be plastically deformed from its constricted

4

diameter to its expanded diameter. The constricted and expanded diameters of stent 100 typically fall in the ranges of 1.0-3.5 mm and 3.5-10.0 mm, respectively.

With reference now to FIGS. 2d-2f, stent 100 is shown overlying a balloon 118 forming part of its catheter delivery system 120. Stent 100 is mounted on its catheter delivery system 120 in its constricted diameter state shown in FIG. 2e for plastic deformation through inflation of balloon 118 to its expanded diameter shown in FIG. 2f for supporting the walls of a bodily conduit. An exemplary stent for implantation in a human coronary artery, is typically 15 mm long made up of five 2.2 mm long segments 102 connected by four 1 mm long connectors 110 and capable of flexion such that its ends subtend a 90° angle at a radius of curvature of approximately 9 mm.

The delivery of articulated stent 100 is considerably simpler than the delivery of prior art articulated stent 10 because stent 100 is equally flexible in all direction and therefore does not require a dedicated angular orientation to pass a particular curved portion. This advantage is particularly important for delivery through blood vessels having multiple curved portions. It is a further advantage of stent 100 over prior art stents 10, that stent 100 provides continuous and uniform support along the entire length of a blood vessel by means of segments 102 and unflexed connectors 110 supporting straight portions thereof while connector portions 114 and 116 supporting convex and concave curved portions thereof, respectively.

With reference now to FIGS. 3a and 3b, an articulated stent 122 is shown in which connectors 124 comprise links 126 having one or more kinks 128. The design of connectors 124 is preferred to that of connector 110 because stent 100 may have a tendency to rupture balloon 118 due to two reasons. First, links 112 overlying the convex portion of balloon 118 have a tendency to be biased inward when stent 100 is flexed. Second, segments 102 display a rotational displacement relative to balloon 118 when stent 100 is expanded.

In this case, the differentially stretched and compressed curved configuration of connector 124 is brought about by two relatively opposing displacements of links 112 as before except that the differential stretching of connectors 124 at convex portion 114 occurs by kinks 128 being somewhat straightened out while the differential compressing of connectors 24 at concave portion 116 occurs by kinks 128 being more acutely bent.

In a similar fashion to stent 100, stent 122 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 3a and 3b and an expanded diameter as shown in FIG. 3c for supporting a bodily conduit when implanted therein.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

What is claimed is:

1. A connector for connecting adjacent areas of adjacent substantially tubular and substantially rigid segments of an articulated stent, the connector comprising:
  - a plurality of flexible links,
  - wherein each of said flexible links includes a plurality of portions with each pair of neighboring portions when viewed laterally having an area of inflection therebetween.
2. A connector according to claim 1 and wherein, during expansion of said stent, said area of inflection of each flexible link remains inflected.

5,980,552

5

3. A connector for connecting adjacent substantially tubular and substantially rigid segments of an expandable articulated stent, comprising:

a flexible link having at least a first portion and a second portion and when viewed laterally an area of inflection disposed between said first portion and said second portion.

4. The connector according to claim 3, wherein said area of inflection remains inflected after the expansion of said stent.

5. The connector of claim 4, wherein said portions are of different lengths and wherein the length of the longer of said portions is not greater than twice the length of the shorter of said portions.

6. The connector of claim 1 or 3, in which the area of inflection enlarges during the expansion of the stent.

7. The connector of claim 1 or 3, in which said portions are generally straight.

8. A connector for connecting adjacent substantially tubular and substantially rigid segments of an expandable articulated stent, comprising:

a flexible link having at least a first portion, a second portion and a third portion, said link when viewed laterally having;

a first area of inflection disposed between said first portion and said second portion; and

6

a second area of inflection disposed between said second portion and said third portion.

9. The connector of claim 8, wherein said first area of inflection and said second area of inflection remain inflected after the expansion of said stent.

10. The connector of claim 8, wherein said portions are of different lengths and wherein the length of the longer of said portions is not greater than twice the length of the shorter of said portions.

11. The connector of claim 8 in which said first area of inflection and said second area of inflection enlarge during the expansion of said stent.

12. The connector of claim 8, in which said portions are generally straight.

13. A connector for connecting segments of an expandable articulated stent, comprising:

a flexible link having at least a first portion, a second portion and a third portion; said link when viewed laterally having an area of inflection disposed between each of said portions, said areas of inflection disposed in substantially opposed directions.

14. The connector according to claim 13, wherein said areas of inflection enlarge during the expansion of said stent.

\* \* \* \* \*

## **EXHIBIT B**





US006059811A

**United States Patent** [19]**Pinchasik et al.**[11] **Patent Number:** **6,059,811**[45] **Date of Patent:** **\*May 9, 2000**[54] **ARTICULATED STENT**[75] **Inventors:** **Gregory Pinchasik; Jacob Richter,**  
both of Ramat Hasharon, Israel[73] **Assignee:** **Medinol Ltd.,** Tel Aviv, Israel[\*] **Notice:** This patent is subject to a terminal disclaimer.[21] **Appl. No.:** **09/026,750**[22] **Filed:** **Feb. 20, 1998****Related U.S. Application Data**

[63] Continuation of application No. 08/760,359, Dec. 4, 1996, which is a continuation of application No. 08/455,462, May 31, 1995, abandoned, which is a continuation of application No. 08/213,272, Mar. 17, 1994, Pat. No. 5,449,373.

[51] **Int. Cl.<sup>7</sup>** ..... **A61M 29/00**[52] **U.S. Cl.** ..... **606/198; 606/194; 623/1; 623/12**[58] **Field of Search** ..... **606/1, 108, 151, 606/154, 155, 158, 200; 623/1, 12**[56] **References Cited****U.S. PATENT DOCUMENTS**

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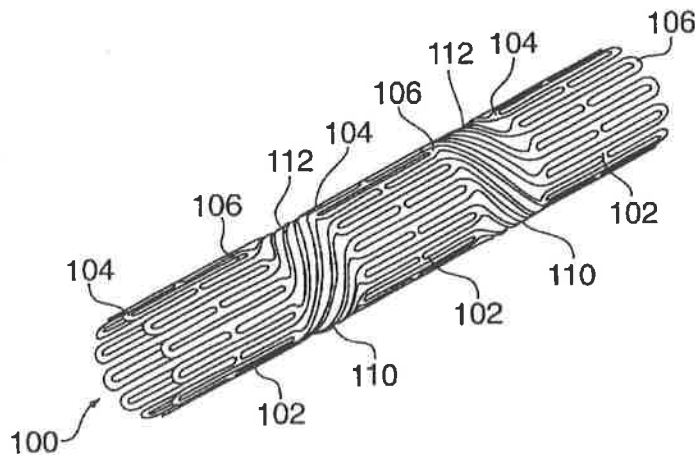
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**Primary Examiner**—Michael Buiz**Assistant Examiner**—William W. Lewis**Attorney, Agent, or Firm**—Kenyon & Kenyon[57] **ABSTRACT**

An articulated stent for delivering through a bodily conduit, for example, a peripheral or coronary artery, which has one or more curved portions and for implantation therein. The articulated stent includes at least two substantially rigid segments and a flexible connector for connecting adjacent segments. The connector assumes a cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

**20 Claims, 5 Drawing Sheets**

U.S. Patent

May 9, 2000

Sheet 1 of 5

6,059,811

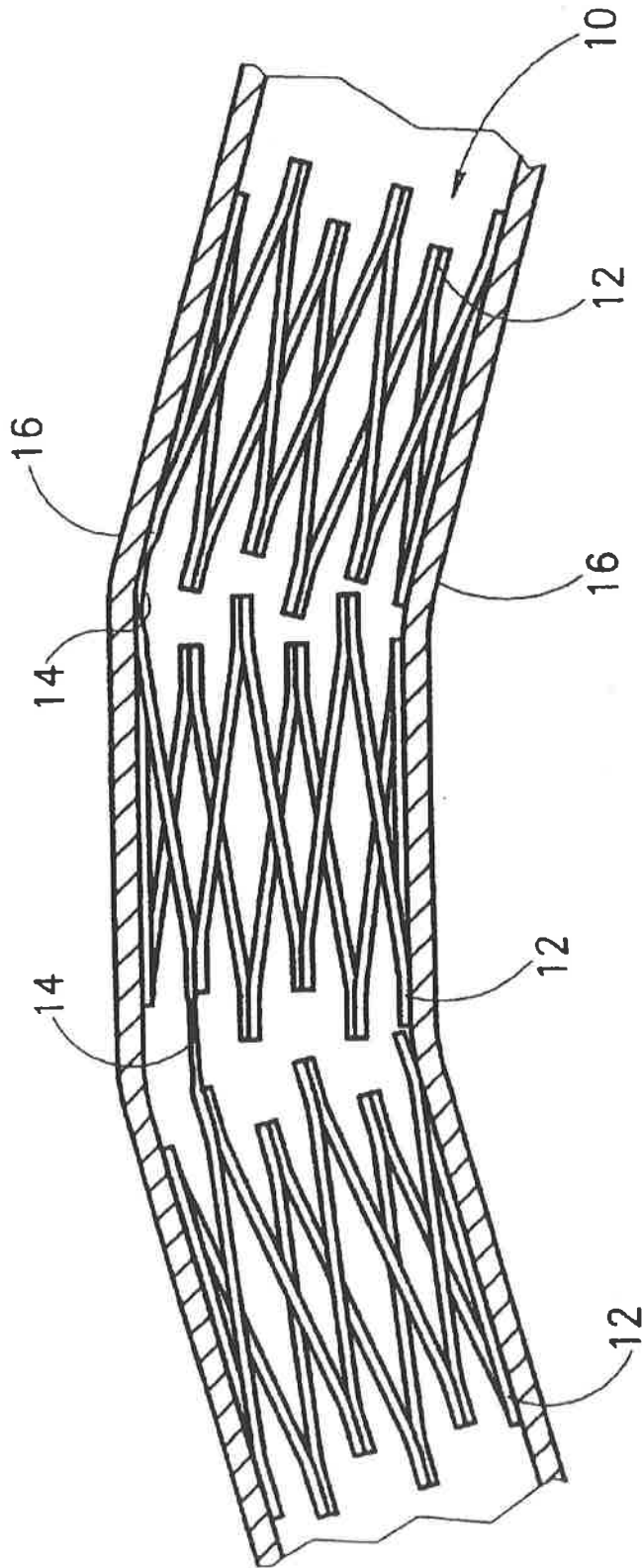


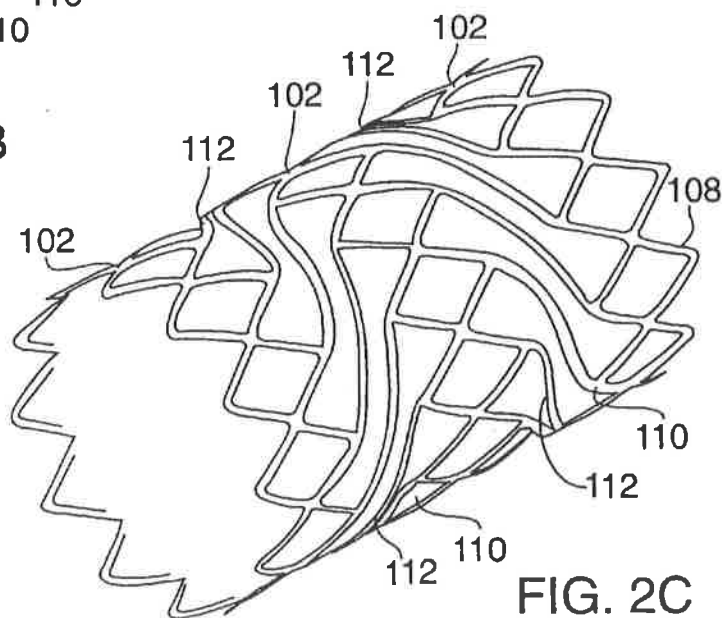
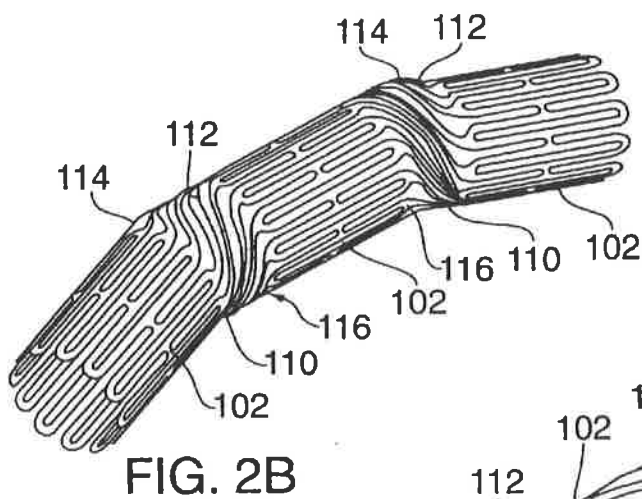
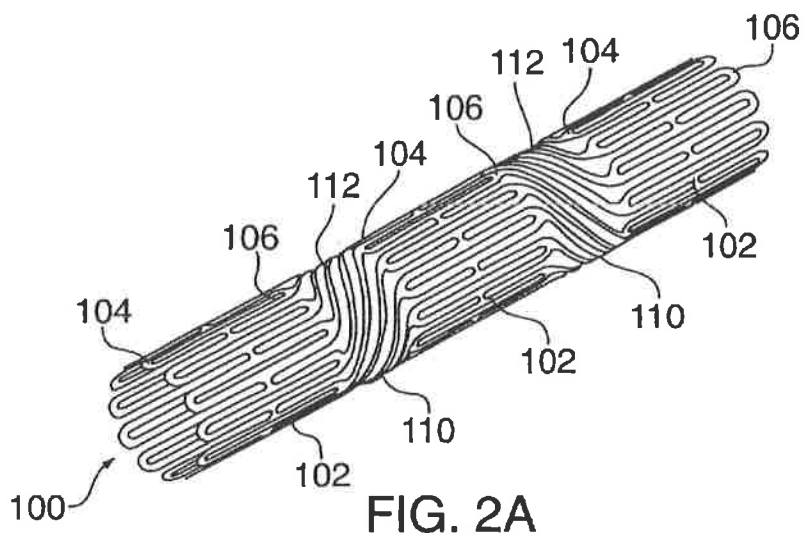
FIG. 1  
PRIOR ART

U.S. Patent

May 9, 2000

Sheet 2 of 5

6,059,811



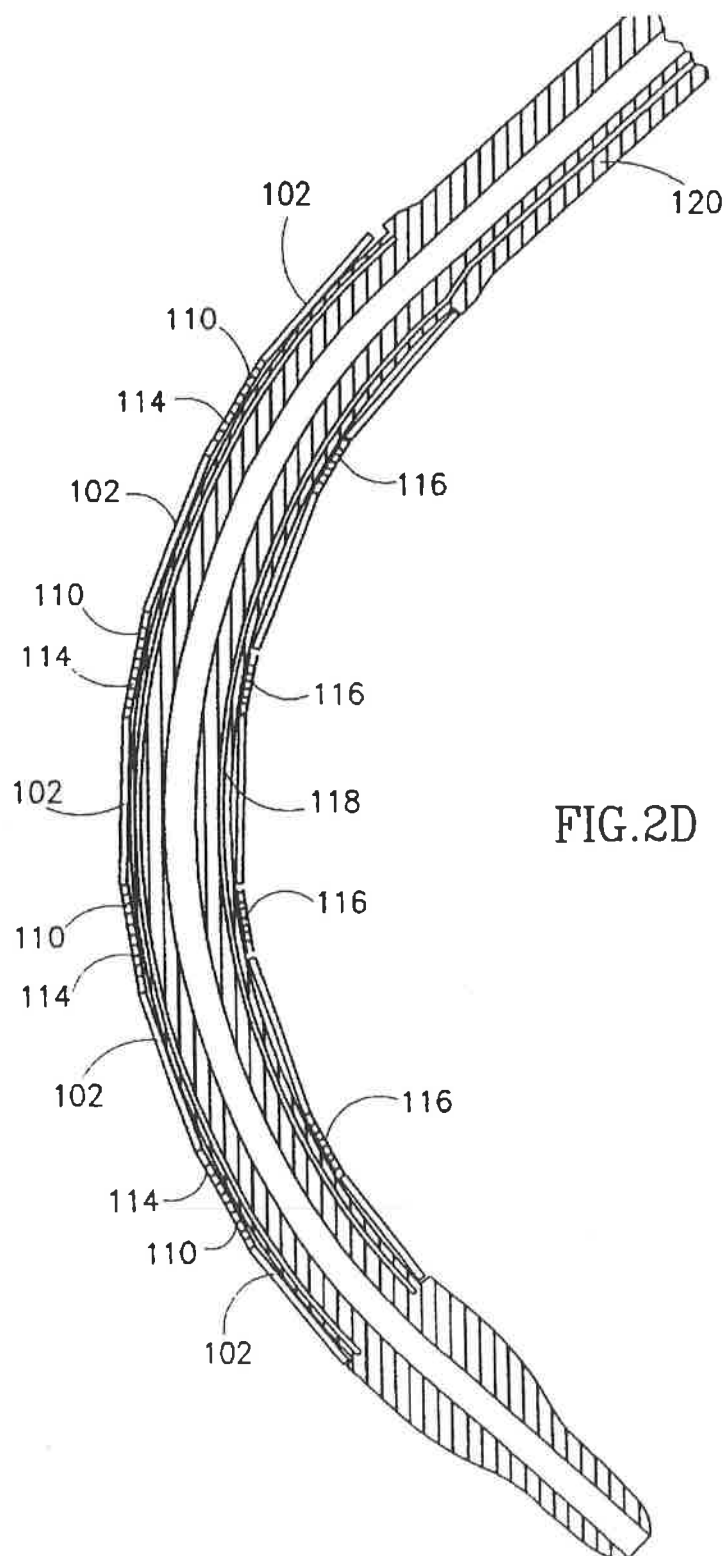


U.S. Patent

May 9, 2000

Sheet 3 of 5

6,059,811



U.S. Patent

May 9, 2000

Sheet 4 of 5

6,059,811

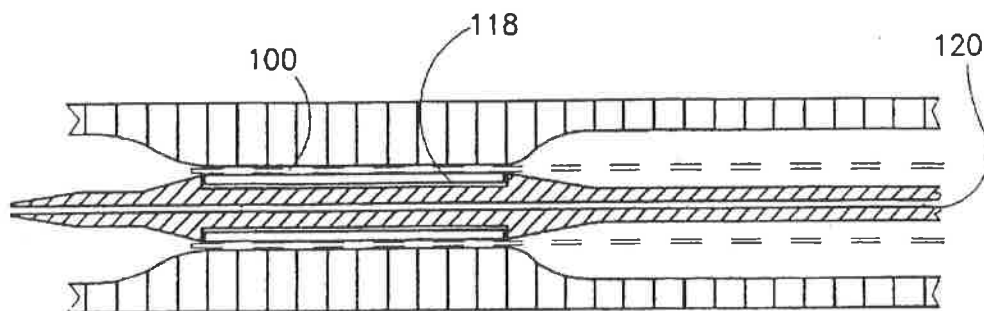


FIG. 2E

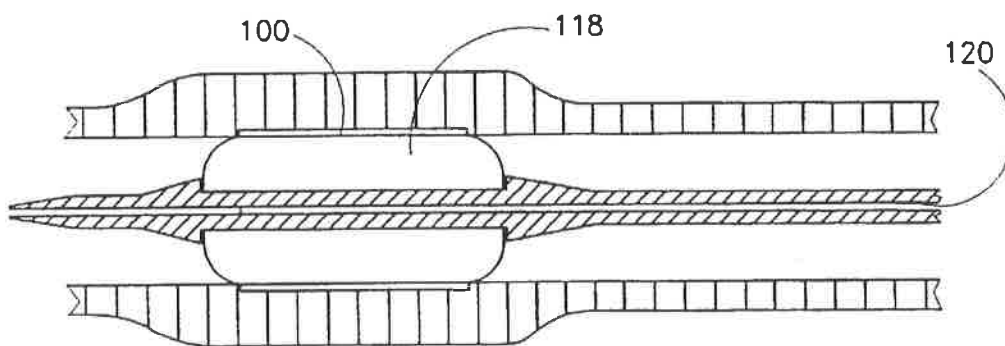


FIG. 2F

U.S. Patent

May 9, 2000

Sheet 5 of 5

6,059,811

FIG. 3A

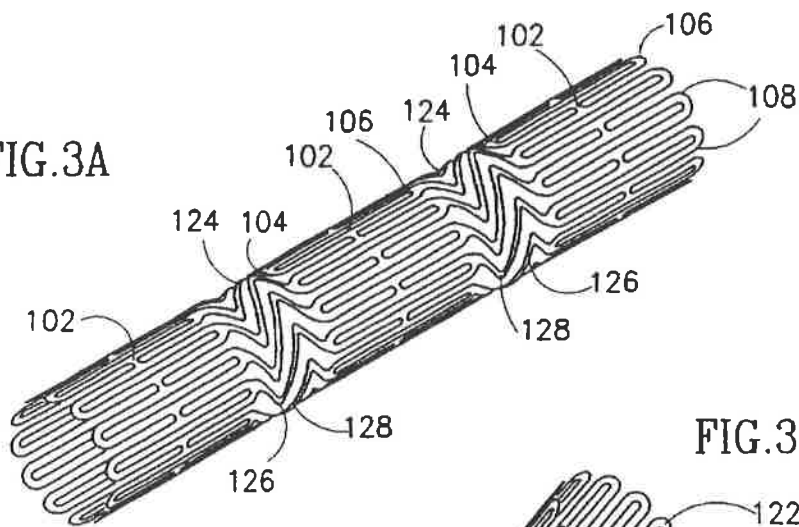


FIG. 3B

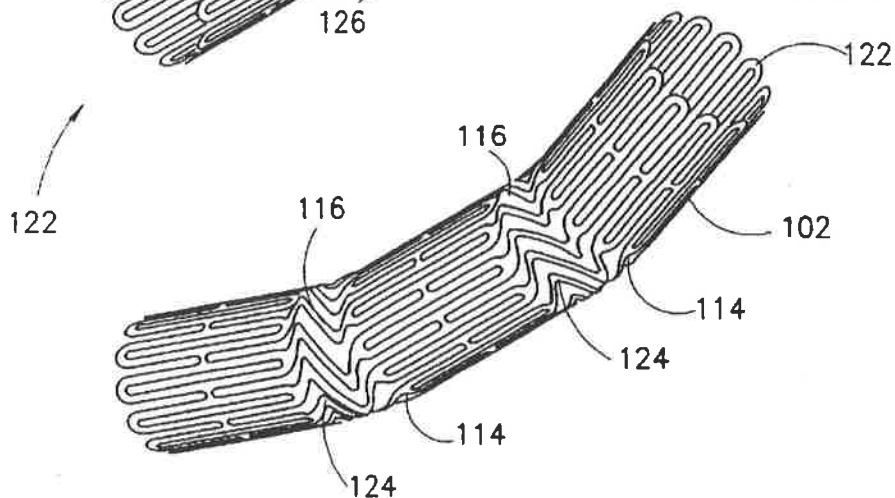
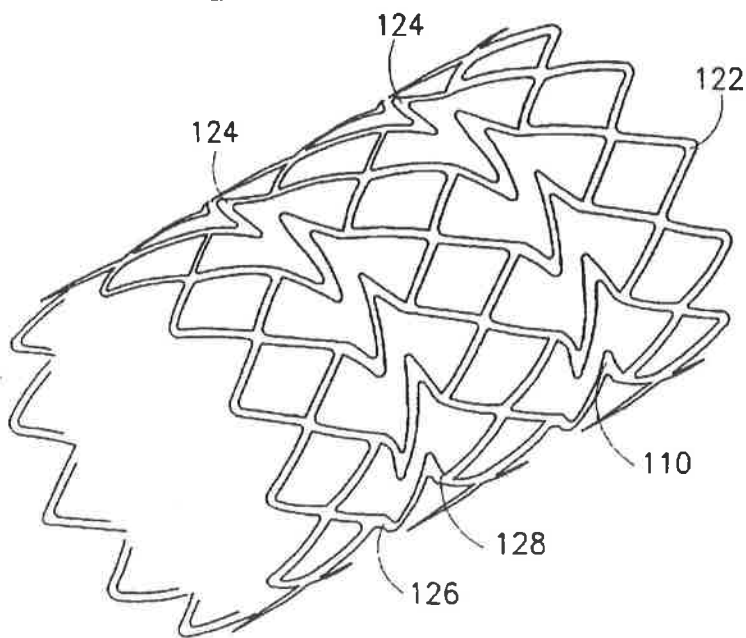


FIG. 3C



6,059,811

1

## ARTICULATED STENT

This application is a continuation of Ser. No. 08/760,359 filed Dec. 4, 1996 which is a continuation of Ser. No. 08/455,462 filed May 31, 1995 abandoned, which is a continuation of Ser. No. 08/213,272 filed Mar. 17, 1994 U.S. Pat. No. 5,449,373.

## FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to stents which are implanted as part of a balloon angioplasty procedure within a bodily conduit of a living animal or a human to maintain patency. In particular, the present invention relates to articulated intravascular stents for delivery through or implantation in a blood vessel having a curved portion.

Intravascular stents having a constricted diameter for delivery through a blood vessel and an expanded diameter for applying a radially outwardly extending force for supporting the blood vessel are known in the art. Articulated intravascular stents for either delivery through a curved blood vessel or implanted therein are also known in the art.

Self-expandable articulated stents are described, for example, in U.S. Pat. No. 5,104,404 entitled "Articulated Stent" to Wolff. Balloon expandable articulated stents are commercially available under the trade name Palmaz-Schatz Balloon-Expandable Stents from Johnson & Johnson Intervention Systems Co.

A prior art self-expandable articulated intravascular stent 10 deployed in a curved blood vessel 16 is now described with reference to FIG. 1 which is, in actual fact, FIG. 2 of the above referenced U.S. Pat. No. 5,104,404. Stent 10 is made up of a number of individual segments 12 articulated by hinges 14 connected at each end to segments 12. Stent 10 is preferably fabricated from memory shape material, for example, nitinol, and as such is self expandable after delivery from a delivery system described in U.S. Pat. No. 4,830,003 to Wolff et al. However, these prior art articulated intravascular stents suffer from a number of disadvantages both during delivery through a curved blood vessel and when implanted therein as will now be described.

The delivery of stent 10 through curved blood vessel 16 is more complicated than the delivery of a non-articulated stent in that stent 10 has to be angularly oriented such that its hinges 14 are located towards the convex portion of blood vessel 16 so that stent 10 can be flexed inward. In the present example, it will be noted that hinges 14 are located on the same side of segments 12 because blood vessel 16 has only a simple curve in one plane. It can be readily appreciated that delivery of stents through blood vessels which have one or more curved portions which are not in the same plane is even more complicated and generally requires specially constructed stents.

Even when implanted in a curved blood vessel 16, stents 10 are shown to be lacking in that the gaps between segments 12 render the curved portion of blood vessel 16 without support. Furthermore, the gaps at the convex portion of blood vessel 16 are substantially greater than the gaps at the concave portion thereof, thereby inducing non-uniform and therefore undesirable stresses on blood vessel 16.

Therefore, it would be highly desirable to have an articulated stent which does not require any particular angular orientation when being delivered through a curved bodily conduit and provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted.

2

It would also be highly desirable the structure of a stent does not depend on the particular orientations of curved portions of a blood vessel.

## SUMMARY OF THE INVENTION

The object of the present invention is for an articulated stent which can be delivered through a curved bodily conduit using a routine medical procedure and a conventional stent delivery system. Furthermore, the stent provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted. Still Further, the structure of a stent and its support of a bodily conduit do not depend on the orientations of the curved portions of the conduit.

The objective of the present invention is achieved by an articulated stent, comprising: (a) at least two substantially rigid segments; and (b) a flexible connector for connecting adjacent segments, wherein the connector assumes a substantially cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

After expansion, the rigid segments of the stent preferably present a fine diamond shaped mesh having 1 mm long sides to provide continuous and uniform support for straight portions of a bodily conduit.

The connectors can be implemented as a plurality of substantially helical links connecting adjacent segments. Alternatively, the connectors can be implemented as links each having at least one kink. The connectors typically have between 8-24 links to provide continuous and uniform support for both straight and curved portions of a bodily conduit.

The stents have constricted diameters for intraluminal delivery and are then deformed, by the inflation of a balloon forming part of their catheter delivery system, to expanded diameters for applying radially outwardly extending forces for supporting the lumen of bodily conduits. The constricted and expanded diameters of the stents typically fall in the ranges of 1.0-3.5 mm and 3.5-10.0 mm, respectively.

The stents are preferably fabricated from low memory, more plastic than elastic, bio-compatible materials, for example, stainless steel 316L, gold, tantalum, etc. which enables them to be plastically deformed from their constricted diameters to their expanded diameters.

A typical stent for implantation in a human coronary artery is 9-21 mm long comprising three to seven 2.2 mm long stent segments connected by two to six 1 mm long connectors such that the ends of the stent subtend between a 45° to 135° angle at a radius of curvature of approximately 9 mm when flexed.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 shows a close-up view of a prior art articulated stent of deployed in a curved blood vessel;

FIGS. 2a and 2b show a preferred embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation;

FIG. 2c shows the expanded stent of FIG. 2 after plastic deformation;

FIG. 2d shows the stent of FIG. 2 mounted on a catheter in its flexed state;



6,059,811

3

FIGS. 2e and 2f show the stent of FIG. 2 before and after expansion by a balloon forming part of its catheter delivery system;

FIGS. 3a and 3b show a second embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation; and

FIG. 3c shows the expanded stent of FIG. 3 after plastic deformation.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of an articulated stent for delivering through a curved bodily conduit, for example, a peripheral or coronary artery of a living animal or a human and implantation therein as part of a balloon angioplasty procedure to maintain patency.

The principles and operation of the articulated stent of the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, FIGS. 2a-2c show an articulated stent, generally designated 100, constructed and operative according to the teachings of the present invention, generally comprising a number of substantially rigid segments 102 connected by connectors 110.

Segments 102 are preferably made up to present a fine diamond mesh of interconnected diamond shaped cells 108 having 1 mm sides on expansion as best seen in FIG. 2c. Depending on the intended diameter of stent 100, segments 102 typically comprise between 8-24 diamond shaped cells 108.

Connectors 110 comprise links 112 connecting a front end 104 to a tail end 106 of adjacent segments 102. Links 112 preferably extend in a substantially helical fashion between apexes of diamond shaped cells 108 at front and rear ends 104 and 106 of adjacent segments 102 such that the number of links 112 equals the number of cells 108. Links 112 are preferably evenly deployed around perimeters of segments 102 such that connectors 110 can be equally flexed in any direction and to provide continuous and uniform support to both straight and curved portions of a bodily conduit.

Alternate connectors 110 at front and rear ends 104 and 106, respectively, of a segment 102 preferably have links 112 wound in clockwise and counter clockwise directions. Alternately winding connectors 110 ensures that the rotational displacement of links 112 and adjacent segments 102 relative to the walls of a blood vessel and more importantly the balloon of its delivery system is minimized when stent 100 is expanded.

It is particular feature of the present invention that connectors 110 have a generally cylindrical configuration when stent 100 is relaxed as best seen in FIG. 2a and a differentially stretched and compressed curved configuration when stent 100 is flexed as best seen in FIG. 2b. The flexed configuration is brought about by two relatively opposing displacements of links 112. First, the differential stretching of connectors 110 occurs at the convex portion thereof denoted 114 by links 112 being displaced away from one another. Second, the differential compressing of connectors 110 occurs at the concave portion thereof denoted 116 by links 112 being displaced towards one another.

Stent 100 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 2a and 2b and an expanded diameter as shown in FIG. 2c for supporting a bodily conduit. Stent 100 is preferably fabricated from low

4

memory, more plastic than elastic, biocompatible material, for example, stainless steel 316L, gold, tantalum, etc. which enables it to be plastically deformed from its constricted diameter to its expanded diameter. The constricted and expanded diameters of stent 100 typically fall in the ranges of 1.0-3.5 mm and 3.5-10.0 mm, respectively.

With reference now to FIGS. 2d-2f, stent 100 is shown overlying a balloon 118 forming part of its catheter delivery system 120. Stent 100 is mounted on its catheter delivery system 120 in its constricted diameter state shown in FIG. 2e for plastic deformation through inflation of balloon 118 to its expanded diameter shown in FIG. 2f for supporting the walls of a bodily conduit. An exemplary stent for implantation in a human coronary artery, is typically 15 mm long made up of five 2.2 mm long segments 102 connected by four 1 mm long connectors 110 and capable of flexion such that its ends subtend a 90° angle at a radius of curvature of approximately 9 mm.

The delivery of articulated stent 100 is considerably simpler than the delivery of prior art articulated stent 10 because stent 100 is equally flexible in all direction and therefore does not require a dedicated angular orientation to pass a particular curved portion. This advantage is particularly important for delivery through blood vessels having multiple curved portions. It is a further advantage of stent 100 over prior art stents 10, that stent 100 provides continuous and uniform support along the entire length of a blood vessel by means of segments 102 and unflexed connectors 110 supporting straight portions thereof while connector portions 114 and 116 supporting convex and concave curved portions thereof, respectively.

With reference now to FIGS. 3a and 3b, an articulated stent 122 is shown in which connectors 124 comprise links 126 having one or more kinks 128. The design of connectors 124 is preferred to that of connector 110 because stent 100 may have a tendency to rupture balloon 118 due to two reasons. First, links 112 overlying the convex portion of balloon 118 have a tendency to be biased inward when stent 100 is flexed. Second, segments 102 display a rotational displacement relative to balloon 118 when stent 100 is expanded.

In this case, the differentially stretched and compressed curved configuration of connector 124 is brought about by two relatively opposing displacements of links 112 as before except that the differential stretching of connectors 124 at convex portion 114 occurs by kinks 128 being somewhat straightened out while the differential compressing of connectors 124 at concave portion 116 occurs by kinks 128 being more acutely bent.

In a similar fashion to stent 100, stent 122 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 3a and 3b and an expanded diameter as shown in FIG. 3c for supporting a bodily conduit when implanted therein.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.

What is claimed is:

1. An expandable articulated stent having a longitudinal axis and a circumferential axis, including:

- a) a plurality of substantially tubular and substantially rigid segments defining a longitudinal aperture, and
- b) a plurality of flexible connecting links connecting said rigid segments, each of said flexible links having a first portion and a second portion, each of said links when

6,059,811

5

viewed laterally having an area of inflection disposed between said portions.

2. The stent of claim 1, wherein each of said flexible connecting links extends between and connects two of said plurality of segments.

3. The stent of claim 2, wherein said plurality of flexible links are provided with end points at which said links are joined to said segments.

4. The stent of claim 3, wherein said end points of said flexible connecting links are aligned substantially longitudinally with said longitudinally extending aperture.

5. The stent of claims 1, 2, 3, or 4 wherein said flexible connecting links are adapted to substantially compensate for the tendency of said segments to foreshorten when said stent is expanded.

6. The stent of claims 1, 2, 3, or 4 wherein said stent is expanded as by an inflatable balloon inflated within said longitudinal aperture.

7. The stent of claims 1, 2, 3, or 4 wherein said flexible connecting links open to longitudinally lengthen and substantially compensate for the longitudinal movement away from each other of the adjacent ends of said connected rigid segments when said stent is expanded.

8. The stent of claims 1, 2, 3, or 4 wherein said segments do not tend to rotate relative to each other when said stent is expanded.

9. The stent of claim 6, wherein at the juncture of said links with said segments there is substantially no component of force from said links in a direction about the circumferential axis of the stent when said stent is expanded.

10. The stent of claim 6, wherein at the juncture of said links with said segments there is substantially no component of force from said links in a direction radial to said longitudinal axis of said longitudinal aperture when said stent is expanded.

11. The stent of claim 10, wherein at the juncture of said links with said segments the only component of force from said links is substantially longitudinal when said stent is expanded.

12. The stent of claims 1, 2, 3, or 4 wherein said links do not tend to project into or outside of said longitudinal aperture of said stent when said stent is expanded.

13. The stent of claims 1, 2, 3, or 4, wherein said links do not tend to project into or outside of said longitudinal aperture of said stent when said stent is flexed.

14. The stent of claim 1, 2, 3, or 4, wherein each of said flexible connecting links has a first end and a second end, said area of inflection is disposed between said first end and said second end, and said area of inflection is provided with a width smaller than the width of said first end and said second end.

15. The stent of claim 1, 2, 3, or 4, wherein each of said segments is provided with apices to which said flexible connecting links are attached, said flexible connecting links having a first end and a second end, said area of inflection disposed between said first end and said second end, said area of inflection provided with a width smaller than the width of said apices of said segments to which said first end and said second end are connected.

16. The stent of claim 1, 2, 3, or 4, wherein said segments display substantially no rotational displacement relative to a balloon disposed in said longitudinal bore when said stent is expanded by said balloon.

17. An expandable articulated stent having a longitudinal axis and a circumferential axis, including:

- a) a plurality of substantially tubular and substantially rigid segments defining a longitudinal aperture, and

6

- b) a plurality of flexible connecting links connecting said rigid segments, each of said flexible links having a first portion and a second portion, each of said links when viewed laterally having an area of inflection disposed between said portions, wherein each of said flexible connecting links extends between and connects two of said plurality of segments, wherein said plurality of flexible links are provided with end points at which said links are joined to said segments, wherein said end points of said flexible connecting links are aligned substantially longitudinally with said longitudinally extending aperture,

wherein said flexible connecting links are adapted to substantially compensate for the tendency of said segments to foreshorten when said stent is expanded, and wherein said stent is expanded as by an inflatable balloon inflated within said longitudinal aperture.

18. An expandable articulated stent having a longitudinal axis and a circumferential axis, including:

- a) a plurality of substantially tubular and substantially rigid segments defining a longitudinal aperture, and
- b) a plurality of flexible connecting links connecting said rigid segments, each of said flexible links having a first portion and a second portion, said link when viewed laterally having an area of inflection disposed between said portions, wherein said stent is expanded as by an inflatable balloon inflated within said longitudinal aperture, wherein said end points of said flexible connecting links are aligned substantially longitudinally with said longitudinally extending aperture, wherein at the juncture of said links with said segments there is substantially no component of force from said links in a direction about the circumferential axis of the stent when said stent is expanded, and wherein at the juncture of said links with said segments there is substantially no component of force from said links in a direction radial to said longitudinal axis of said longitudinal aperture when said stent is expanded.

19. An expandable articulated stent having a longitudinal axis and a circumferential axis, including:

- a) a plurality of substantially tubular and substantially rigid segments defining a longitudinal aperture, and
- b) a plurality of flexible connecting links connecting said rigid segments, each of said flexible links having a first portion and a second portion, each of said links when viewed laterally having an area of inflection disposed between said portions,

wherein said stent is expanded as by an inflatable balloon inflated within said longitudinal aperture, wherein said links do not tend to project into or outside of said longitudinal aperture of said stent when said stent is expanded, and wherein said links do not tend to project into or outside of said longitudinal aperture of said stent when said stent is flexed.

20. An expandable articulated stent having a longitudinal axis and a circumferential axis, including:

- a) a plurality of substantially tubular and substantially rigid segments defining a longitudinal aperture, and
- b) a plurality of flexible connecting links connecting said rigid segments, each of said flexible links having a first portion and a second portion, each of said links when viewed laterally having an area of inflection disposed between said portions, wherein said stent is expanded as by an inflatable balloon inflated within said longitudinal aperture, wherein each of said flexible connecting links has a first end and a second end, said area of

6,059,811

7

inflection is disposed between said first end and said second end, and said area of inflection is provided with a width smaller than the width of said first end and said second end,

wherein each of said segments is provided with apexes to which said flexible connecting links are attached, said flexible connecting links having a first end and a second end, said area of inflection disposed between said first end and said second end, said area of inflection provided with a

8

width smaller than the width of said apexes of said segments to which said first end and said second end are connected, and wherein said segments display substantially no rotational displacement relative to a balloon disposed in said longitudinal bore when said stent is expanded by said balloon.

\* \* \* \* \*



## **EXHIBIT C**



US006589276B2

(12) **United States Patent**  
**Pinchasik et al.**

(10) **Patent No.:** **US 6,589,276 B2**  
(45) **Date of Patent:** **Jul. 8, 2003**

(54) **ARTICULATED STENT**

(75) **Inventors:** **Gregory Pinchasik, Ramat Hasbaron (IL); Jacob Richter, Ramat Hasbaron (IL)**

(73) **Assignee:** **Medinol Ltd., Tel Aviv (IL)**

(\*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(21) **Appl. No.:** **10/292,759**

(22) **Filed:** **Nov. 13, 2002**

(65) **Prior Publication Data**

US 2003/0065384 A1 Apr. 3, 2003

#### Related U.S. Application Data

(63) Continuation of application No. 09/483,082, filed on Jan. 14, 2000, now Pat. No. 6,508,834, which is a continuation of application No. 09/026,750, filed on Feb. 20, 1998, now Pat. No. 6,059,811, which is a continuation of application No. 08/760,359, filed on Dec. 4, 1996, now Pat. No. 5,980,552, which is a continuation of application No. 08/455,462, filed on May 31, 1995, now abandoned, which is a continuation of application No. 08/213,272, filed on Mar. 17, 1994, now Pat. No. 5,449,373.

(51) **Int. Cl.<sup>7</sup>** ..... **A61F 2/06**

(52) **U.S. Cl.** ..... **623/1.16**

(58) **Field of Search** ..... **623/1.15, 1.16, 623/1.17, 1.18, 1.11; 606/108, 194, 195**

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*Primary Examiner*—David H. Willse

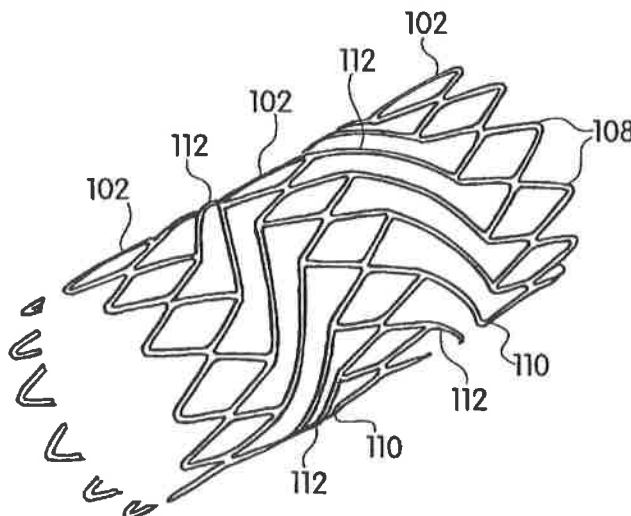
*Assistant Examiner*—Suzette J. Jackson

(74) *Attorney, Agent, or Firm*—Kenyon & Kenyon

(57) **ABSTRACT**

An articulated stent for delivering through a bodily conduit, for example, a peripheral or coronary artery, which has one or more curved portions and for implantation therein. The articulated stent includes at least two substantially rigid segments and a flexible connector for connecting adjacent segments. The connector assumes a cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

**16 Claims, 5 Drawing Sheets**



## US 6,589,276 B2

Page 2

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U.S. Patent

Jul. 8, 2003

Sheet 1 of 5

US 6,589,276 B2

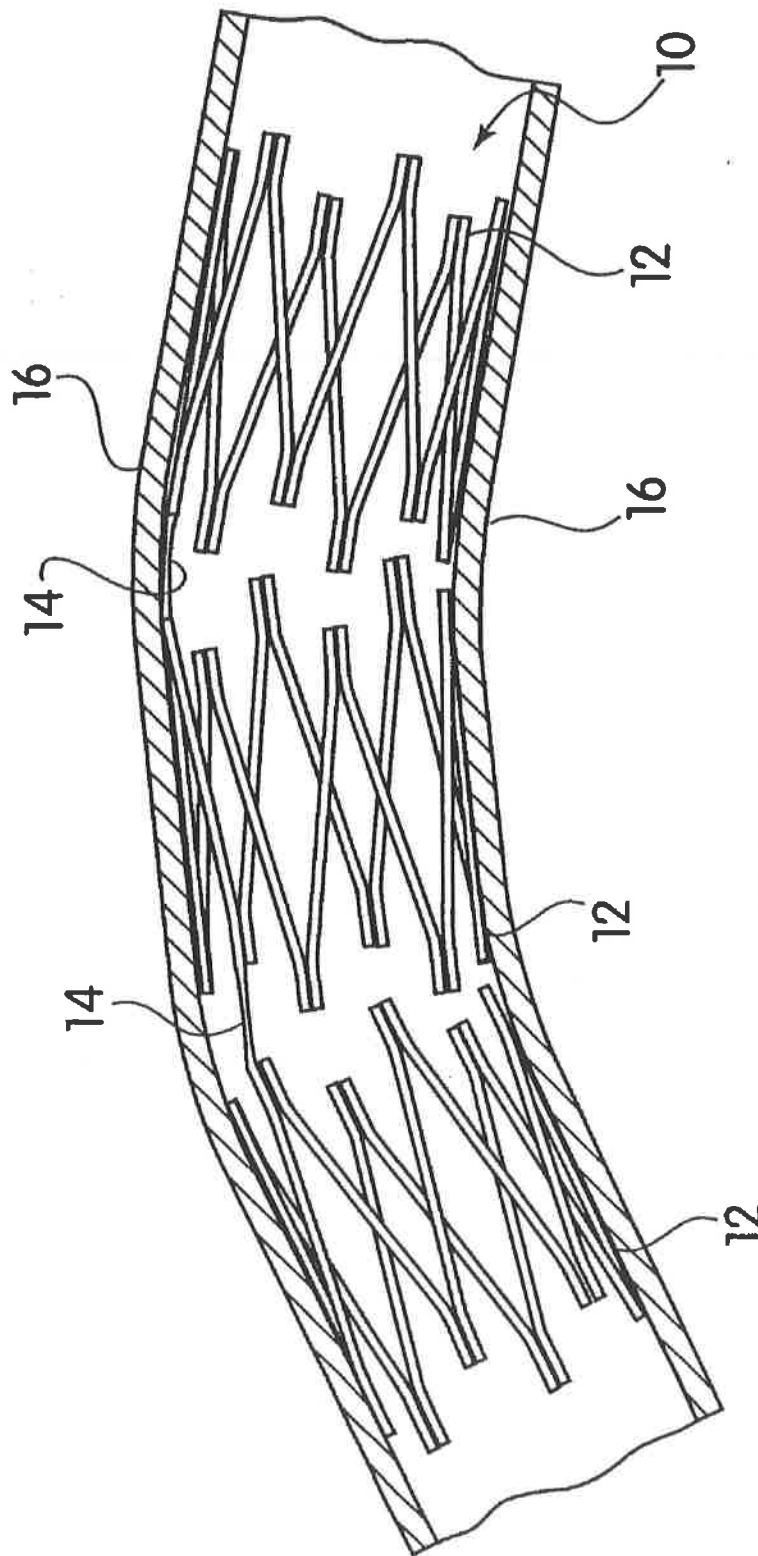


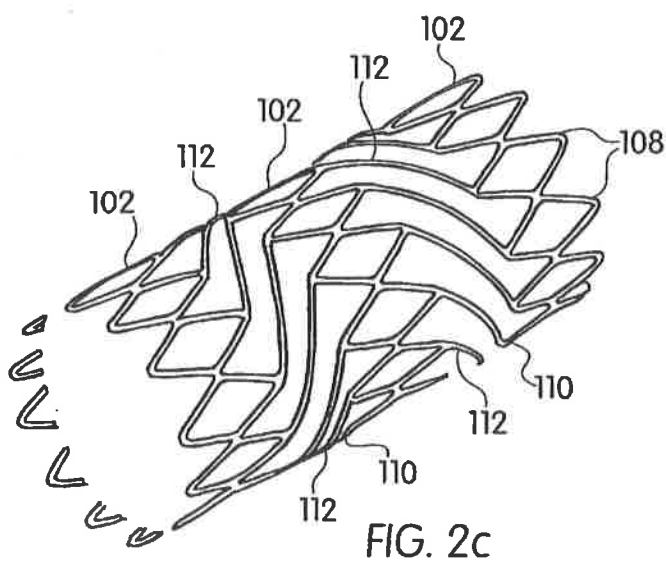
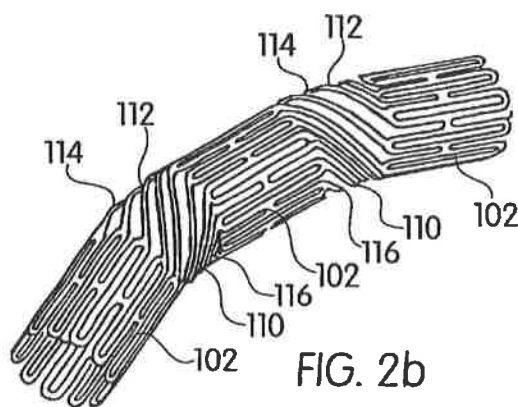
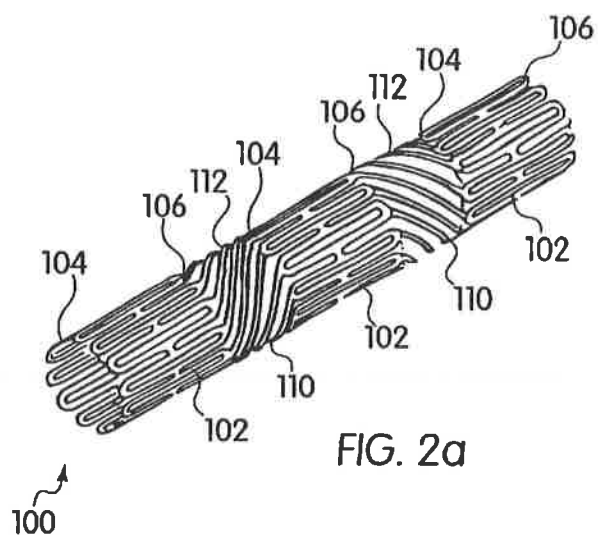
FIG. 1 (Prior Art)

U.S. Patent

Jul. 8, 2003

Sheet 2 of 5

US 6,589,276 B2

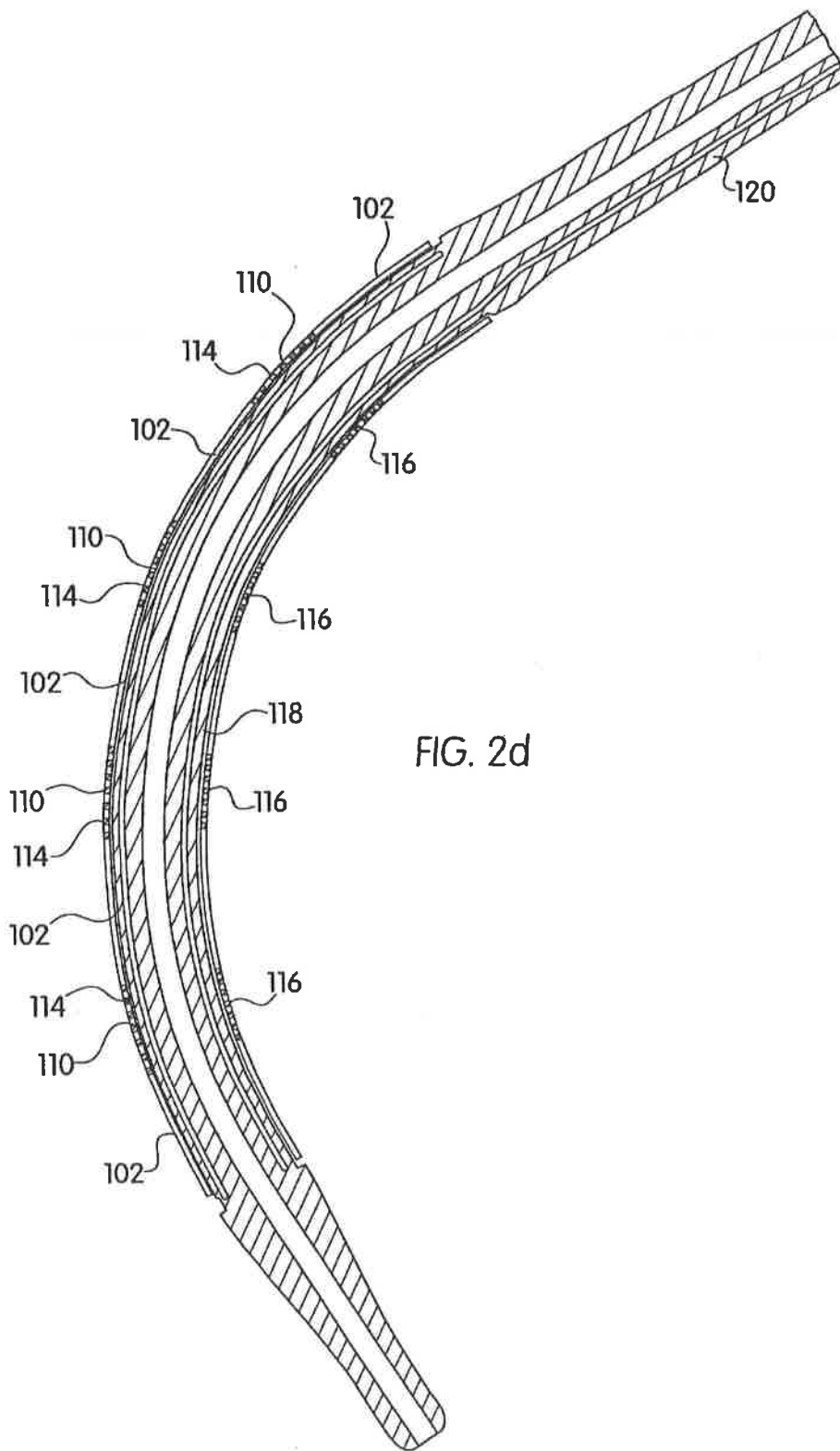


U.S. Patent

Jul. 8, 2003

Sheet 3 of 5

US 6,589,276 B2



U.S. Patent

Jul. 8, 2003

Sheet 4 of 5

US 6,589,276 B2

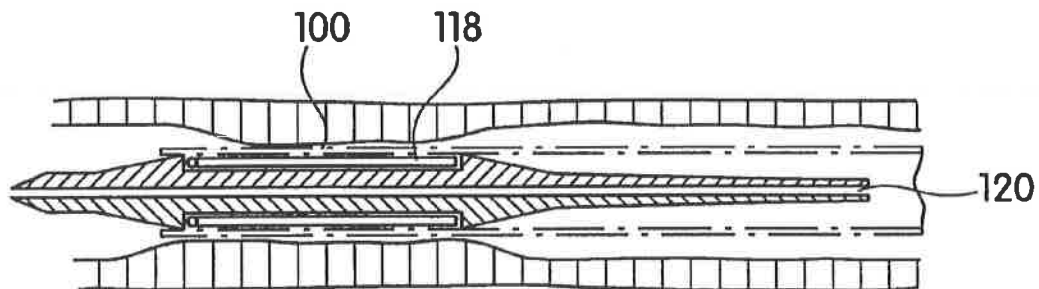


FIG. 2e

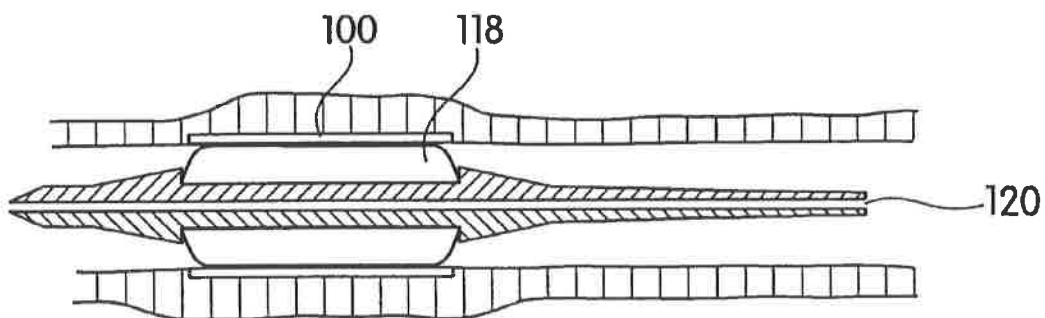


FIG. 2f

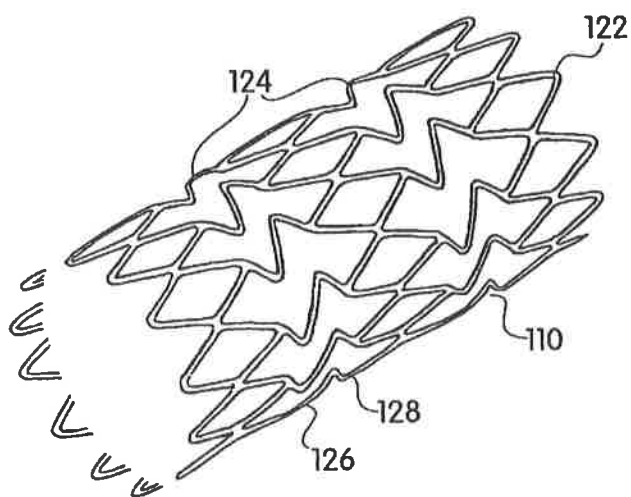
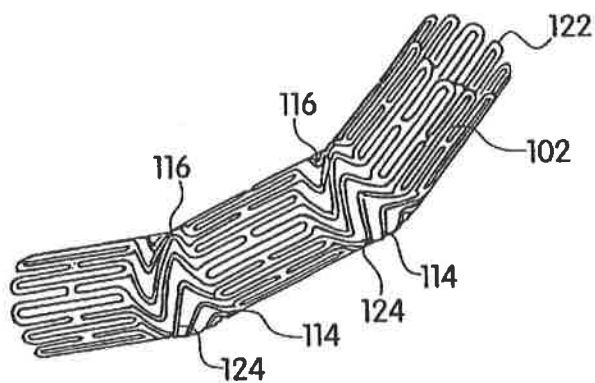
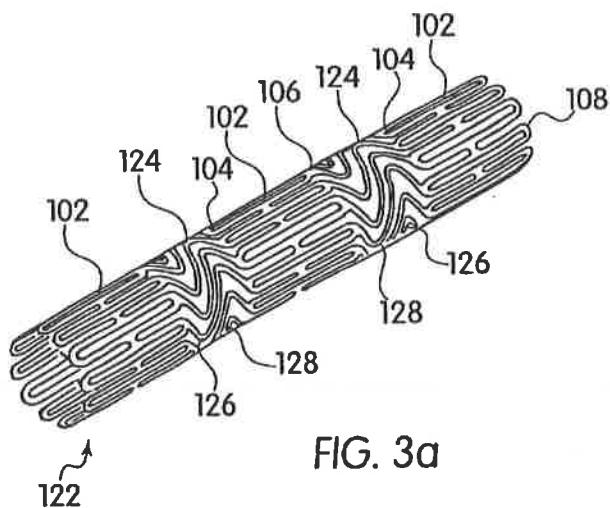


U.S. Patent

Jul. 8, 2003

Sheet 5 of 5

US 6,589,276 B2



US 6,589,276 B2

1

## ARTICULATED STENT

## RELATED PATENT APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 09/483,082 filed on Jan. 14, 2000 now U.S. Pat. No. 6,508,834 which is a continuation of U.S. patent application Ser. No. 09/026,750 filed Feb. 20, 1998 (now U.S. Pat. No. 6,059,811), which is a continuation of U.S. patent application Ser. No. 08/760,359 filed Dec. 4, 1996 (now U.S. Pat. No. 5,980,552), which is a continuation of U.S. patent application Ser. No. 08/455,462 filed May 31, 1995 (abandoned), which is a continuation of U.S. patent application Ser. No. 08/213,272 filed Mar. 17, 1994 (now U.S. Pat. No. 5,449,373).

## FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to stents which are implanted as part of a balloon angioplasty procedure within a bodily conduit of a living animal or a human to maintain patency. In particular, the present invention relates to articulated intravascular stents for delivery through or implantation in a blood vessel having a curved portion.

Intravascular stents having a constricted diameter for delivery through a blood vessel and an expanded diameter for applying a radially outwardly extending force for supporting the blood vessel are known in the art. Articulated intravascular stents for either delivery through a curved blood vessel or implanted therein are also known in the art.

Self-expandable articulated stents are described, for example, in U.S. Pat. No. 5,104,404 entitled "Articulated Stent" to Wolff. Balloon expandable articulated stents are commercially available under the trade name Palmaz-Schatz Balloon-Expandable Stents from Johnson & Johnson Intervention Systems Co.

A prior art self-expandable articulated intravascular stent 10 deployed in a curved blood vessel 16 is now described with reference to FIG. 1 which is, in actual fact, FIG. 2 of the above referenced U.S. Pat. No. 5,104,404. Stent 10 is made up of a number of individual segments 12 articulated by hinges 14 connected at each end to segments 12. Stent 10 is preferably fabricated from memory shape material, for example, nitinol, and as such is self expandable after delivery from a delivery system described in U.S. Pat. No. 4,830,003 to Wolff et al. However, these prior art articulated intravascular stents suffer from a number of disadvantages both during delivery through a curved blood vessel and when implanted therein as will now be described.

The delivery of stent 10 through curved blood vessel 16 is more complicated than the delivery of a non-articulated stent in that stent 10 has to be angularly oriented such that its hinges 14 are located towards the convex portion of blood vessel 16 so that stent 10 can be flexed inward. In the present example, it will be noted that hinges 14 are located on the same side of segments 12 because blood vessel 16 has only a simple curve in one plane. It can be readily appreciated that delivery of stents through blood vessels which have one or more curved portions which are not in the same plane is even more complicated and generally requires specially constructed stents.

Even when implanted in a curved blood vessel 16, stents 10 are shown to be lacking in that the gaps between segments 12 render the curved portion of blood vessel 16 without support. Furthermore, the gaps at the convex portion of blood vessel 16 are substantially greater than the gaps at

2

the concave portion thereof, thereby inducing non-uniform and therefore undesirable stresses on blood vessel 16.

Therefore, it would be highly desirable to have an articulated stent which does not require any particular angular orientation when being delivered through a curved bodily conduit and provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted.

It would also be highly desirable, the structure of a stent does not depend on the particular orientations of curved portions of a blood vessel.

## SUMMARY OF THE INVENTION

The object of the present invention is for an articulated stent which can be delivered through a curved bodily conduit using a routine medical procedure and a conventional stent delivery system. Furthermore, the stent provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted. Still further, the structure of a stent and its support of a bodily conduit do not depend on the orientations of the curved portions of the conduit.

The objective of the present invention is achieved by an articulated stent, comprising: (a) at least two substantially rigid segments; and (b) a flexible connector for connecting adjacent segments, wherein the connector assumes a substantially cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

After expansion the rigid segments of the stent preferably present a fine diamond shaped mesh having 1 mm long sides to provide continuous and uniform support for straight portions of a bodily conduit.

The connectors can be implemented as a plurality of substantially helical links connecting adjacent segments. Alternatively, the connectors can be implemented as links each having at least one kink. The connectors typically have between 8-24 links to provide continuous and uniform support for both straight and curved portions of a bodily conduit.

The stents have constricted diameters for intraluminal delivery and are then deformed, by the inflation of a balloon forming part of their catheter delivery system, to expanded diameters for applying radially outwardly extending forces for supporting the lumen of bodily conduits. The constricted and expanded diameters of the stents typically fall in the ranges of 10-3.5 mm and 3.5-10.0 mm, respectively.

The stents are preferably fabricated from low memory, more plastic than elastic, bio-compatible materials, for example, stainless steel 316L, gold, tantalum, etc. which enables them to be plastically deformed from their constricted diameters to their expanded diameters.

A typical stent for implantation in a human coronary artery is 9-21 mm long comprising three to seven 2.2 mm long stent segments connected by two to six 1 mm long connectors such that the ends of the stent subtend between a 45° to 135° angle at a radius of curvature of approximately 9 mm when flexed.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

FIG. 1 shows a close-up view of a prior art articulated stent of deployed in a curved blood vessel;

US 6,589,276 B2

3

FIGS. 2a and 2b show a preferred embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation;

FIG. 2c shows the expanded stent of FIG. 2 after plastic deformation;

FIG. 2d shows the stent of FIG. 2 mounted on a catheter in its flexed state;

FIGS. 2e and 2f show the stent of FIG. 2 before and after expansion by a balloon forming part of its catheter delivery system;

FIGS. 3a and 3b show a second embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation; and

FIG. 3c shows the expanded stent of FIG. 3 after plastic deformation.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of an articulated stent for delivering through a curved bodily conduit, for example, a peripheral or coronary artery of a living animal or a human and implantation therein as part of a balloon angioplasty procedure to maintain patency.

The principles and operation of the articulated stent of the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, FIGS. 2a-2c show an articulated tent, Generally designated 100, constructed and operative according to the teachings of the present invention, generally comprising a number of substantially rigid segments 102 connected by connectors 110.

Segments 102 are preferably made up to present a fine diamond mesh of interconnected diamond shaped cells 108 having 1 mm sides on expansion as best seen in FIG. 2c. Depending on the intended diameter of stent 100, segments 102 typically comprise between 8-24 diamond shaped cells 108.

Connectors 110 comprise links 112 connecting a front end 104 to tail end 106 of adjacent segments 102. Links 112 preferably extend in a substantially helical fashion between apexes of diamond shaped cells 108 at front and rear ends 104 and 106 of adjacent segments 102 such that the number of links 112 equals the number of cells 108. Links 112 are preferably evenly deployed around perimeters of segments 102 such that connectors 110 can be equally flexed in any direction and to provide continuous and uniform support to both straight and curved portions of a bodily conduit.

Alternate connectors 110 at front and rear ends 104 and 106, respectively, of a segment 102 preferably have links 112 wound in clockwise and counter clockwise directions. Alternately winding connectors 110 ensures that the rotational displacement of links 112 and adjacent segments 102 relative to the walls of a blood vessel and more importantly the balloon of its delivery system is minimized when stent 100 is expanded.

It is particular feature of the present invention that connectors 110 have a generally cylindrical configuration when stent 100 is relaxed as best seen in FIG. 2a and a differentially stretched and compressed curved configuration when stent 100 is flexed as best seen in FIG. 2b. The flexed configuration is brought about by two relatively opposing displacements of links 112. First, the differential stretching of connectors 110 occurs at the convex portion thereof

4

denoted 114 by links 112 being displaced away from one another. Second, the differential compressing of

connectors 110 occurs at the concave portion thereof denoted 116 by links 112 being displaced towards one another.

Stent 100 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 2a and 2b and an expanded diameter as shown in FIG. 2c for supporting a bodily conduit. Stent 100 is preferably fabricated from low memory, more plastic than elastic, bio-compatible material, for example, stainless steel 316L, gold, tantalum, etc. which enables it to be plastically deformed from its constricted diameter to its expanded diameter. The constricted and expanded diameters of stent 100 typically fall in the ranges of 1.0-3.5 mm and 3.5-10.0 mm, respectively.

With reference now to FIGS. 2d-2f, stent 100 is shown overlying a balloon 118 forming part of its catheter delivery system 120. Stent 100 is mounted on its catheter delivery system 120 in its constricted diameter state shown in FIG. 2e for plastic deformation through inflation of balloon 118 to its expanded diameter shown in FIG. 2f for supporting the walls of a bodily conduit. An exemplary stent for implantation in a human coronary artery, is typically 15 mm long, made up of five 2.2 mm long segments 102 connected by four 1 mm long connectors 110 and capable of flexion such that its ends subtend a 90° angle at a radius of curvature of approximately 9 mm.

The delivery of articulated stent 100 is considerably simpler than the delivery of prior art articulated stent 10 because stent 100 is equally flexible in all direction and therefore does not require a dedicated angular orientation to pass a particular curved portion. This advantage is particularly important for delivery through blood vessels having multiple curved portions. It is a further advantage of stent 100 over prior art stents 10, that stent 100 provides continuous and uniform support along the entire length of a blood vessel by means of segments 102 and unflexed connectors 110 supporting straight portions thereof while connector portions 114 and 116 supporting convex and concave curved portions thereof, respectively.

With reference now to FIGS. 3a and 3b, an articulated stent 122 is shown in which connectors 124 comprise links 126 having one or more kinks 128. The design of connectors 124 is preferred to that of connector 110 because stent 100 may have a tendency to rupture balloon 118 due to two reasons. First, links 112 overlying the convex portion of balloon 118 have a tendency to be biased inward when stent 100 is flexed. Second, segments 102 display a rotational displacement relative to balloon 118 when stent 100 is expanded.

In this case, the differentially stretched and compressed curved configuration of connector 124 is brought about by two relatively opposing displacements of links 112 as before except that the differential stretching of connectors 124 at convex portion 114 occurs by kinks 128 being somewhat straightened out while the differential compressing of connectors 124 at concave portion 116 occurs by kinks 128 being more acutely bent.

In a similar fashion to stent 100, stent 122 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 3a and 3b and an expanded diameter as shown in FIG. 3c for supporting a bodily conduit when implanted therein.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that many variations, modifications and other applications of the invention may be made.



US 6,589,276 B2

5

What is claimed is:

1. An expandable stent comprising:

(a) at least two substantially rigid segments,

- (i) each of said substantially rigid segments having a plurality of U or V-shaped regions in both the expanded and unexpanded configuration, the U or V-shaped regions being more open in the expanded configuration than in the unexpanded configuration,
- (ii) each of said substantially rigid segments presenting a substantially cylindrical structure defining a longitudinal passageway therethrough in both the expanded and unexpanded configurations, the cylindrical structure being shorter in length and wider in diameter in the expanded configuration than in the unexpanded configuration,

(b) a flexible connector comprising a plurality of flexible links disposed between and connecting adjacent substantially rigid segments,

- (i) each of said flexible links connecting a U or V-shaped region of a substantially rigid segment with the nearest U or V-shaped region of the adjacent substantially rigid segment,
- (ii) each of said flexible links, when viewed laterally, having a first portion, a second portion and at least one area of inflection disposed between the first portion and the second portion, and
- (iii) none of said flexible links projecting into said longitudinal passageway in the unexpanded configuration.

2. An expandable stent in accordance with claim 1, wherein each of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, is connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

3. An expandable stent in accordance with claim 1, wherein substantially all of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, are connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

4. An expandable stent in accordance with claim 1, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

5. An expandable stent in accordance with claim 1 wherein the first portion and second portion are substantially straight.

6. An expandable stent in accordance with claim 1 wherein said stent is expanded by an inflatable balloon inflated within said longitudinal aperture.

7. An expandable stent comprising:

(a) at least two substantially rigid segments,

- (i) each of said substantially rigid segments having a plurality of U or V-shaped regions in both the expanded and unexpanded configuration, the U or V-shaped regions being more open in the expanded configuration than in the unexpanded configuration,
- (ii) each of said substantially rigid segments presenting a substantially cylindrical structure defining a longitudinal passageway therethrough in both the expanded and unexpanded configurations, the cylindrical structure being shorter in length and wider in diameter in the expanded configuration than in the unexpanded configuration,

(b) a flexible connector comprising a plurality of flexible links disposed between and connecting adjacent substantially rigid segments,

- (i) each of said flexible links having end points which are aligned substantially parallel to the longitudinal axis of the stent,

6

- (ii) each of said flexible links, when viewed laterally, having a first portion, a second portion and at least one area of inflection disposed between the first portion and the second portion, and

- (iii) none of said flexible links projecting into said longitudinal passageway in the unexpanded configuration.

8. An expandable stent in accordance with claim 7, wherein each of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, is connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

9. An expandable stent in accordance with claim 7, wherein substantially all of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, are connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

10. An expandable stent in accordance with claim 7, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

11. An expandable stent in accordance with claim 7, wherein the first portion and second portion are substantially straight.

12. An expandable stent in accordance with claim 7, wherein said stent is expanded by an inflatable balloon inflated within said longitudinal aperture.

13. An expandable stent comprising:

(a) at least two substantially rigid segments,

- (i) each of said substantially rigid segments having a plurality of U or V-shaped regions in both the expanded and unexpanded configuration, the U or V-shaped regions being more open in the expanded configuration than in the unexpanded configuration,
- (ii) each of said substantially rigid segments presenting a substantially cylindrical structure defining a longitudinal passageway therethrough in both the expanded and unexpanded configurations, the cylindrical structure being wider in diameter in the expanded configuration than in the unexpanded configuration,

(b) a flexible connector comprising a plurality of flexible links disposed between and connecting adjacent substantially rigid segments,

- (i) each of said flexible links connecting a U or V-shaped region of a substantially rigid segment with the nearest U or V-shaped region of the adjacent substantially rigid segment,
- (ii) each of said flexible links, when viewed laterally, having a first portion, a second portion and at least one area of inflection disposed between the first portion and the second portion, and
- (iii) none of said flexible links projecting into said longitudinal passageway in the unexpanded configuration.

14. An expandable stent in accordance with claim 13, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

15. An expandable stent in accordance with claim 13, wherein the first portion and second portion are substantially straight.

16. An expandable stent in accordance with claim 13, wherein said stent is expanded by an inflatable balloon inflated within said longitudinal aperture.

\* \* \* \* \*

## **EXHIBIT D**



US006875228B2

(12) **United States Patent**  
**Pinchasik et al.**

(10) **Patent No.:** **US 6,875,228 B2**  
(45) **Date of Patent:** **\*Apr. 5, 2005**

(54) **ARTICULATED STENT**

(75) **Inventors:** **Gregory Pinchasik, Ramat Basharon (IL); Jacob Richter, Ramat Basharon (IL)**

(73) **Assignee:** **Medinol, Ltd., Tel Aviv (IL)**

(\*) **Notice:** Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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*Primary Examiner*—David H. Willse

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(74) *Attorney, Agent, or Firm*—Morgan & Finnegan, L.L.P.

(57) **ABSTRACT**

An articulated stent for delivering through a bodily conduit, for example, a peripheral or coronary artery, which has one or more curved portions and for implantation therein. The articulated stent includes at least two substantially rigid segments and a flexible connector for connecting adjacent segments. The connector assumes a cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

This patent is subject to a terminal disclaimer.

(21) **Appl. No.:** **10/442,171**

(22) **Filed:** **May 21, 2003**

(65) **Prior Publication Data**

US 2003/0195616 A1 Oct. 16, 2003

**Related U.S. Application Data**

(63) Continuation of application No. 10/292,759, filed on Nov. 13, 2002, now Pat. No. 6,589,276, which is a continuation of application No. 09/483,082, filed on Jan. 14, 2000, now Pat. No. 6,508,834, which is a continuation of application No. 09/026,750, filed on Feb. 20, 1998, now Pat. No. 6,059,811, which is a continuation of application No. 08/760,359, filed on Dec. 4, 1996, now Pat. No. 5,980,552, which is a continuation of application No. 08/455,462, filed on May 31, 1995, now abandoned, which is a continuation of application No. 08/213,272, filed on Mar. 17, 1994, now Pat. No. 5,449,373.

(51) **Int. Cl.<sup>7</sup>** ..... **A61F 2/06**

(52) **U.S. Cl.** ..... **623/1.16**

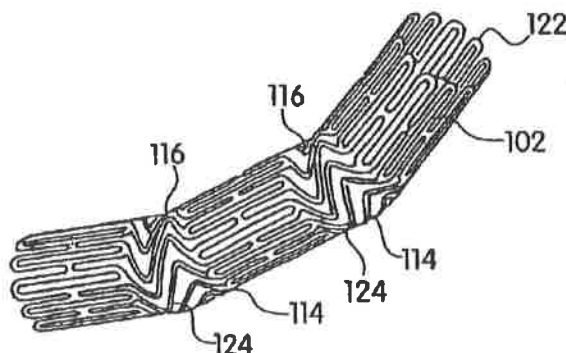
(58) **Field of Search** ..... **623/1.11-1.22**

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**22 Claims, 5 Drawing Sheets**





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U.S. Patent

Apr. 5, 2005

Sheet 1 of 5

US 6,875,228 B2

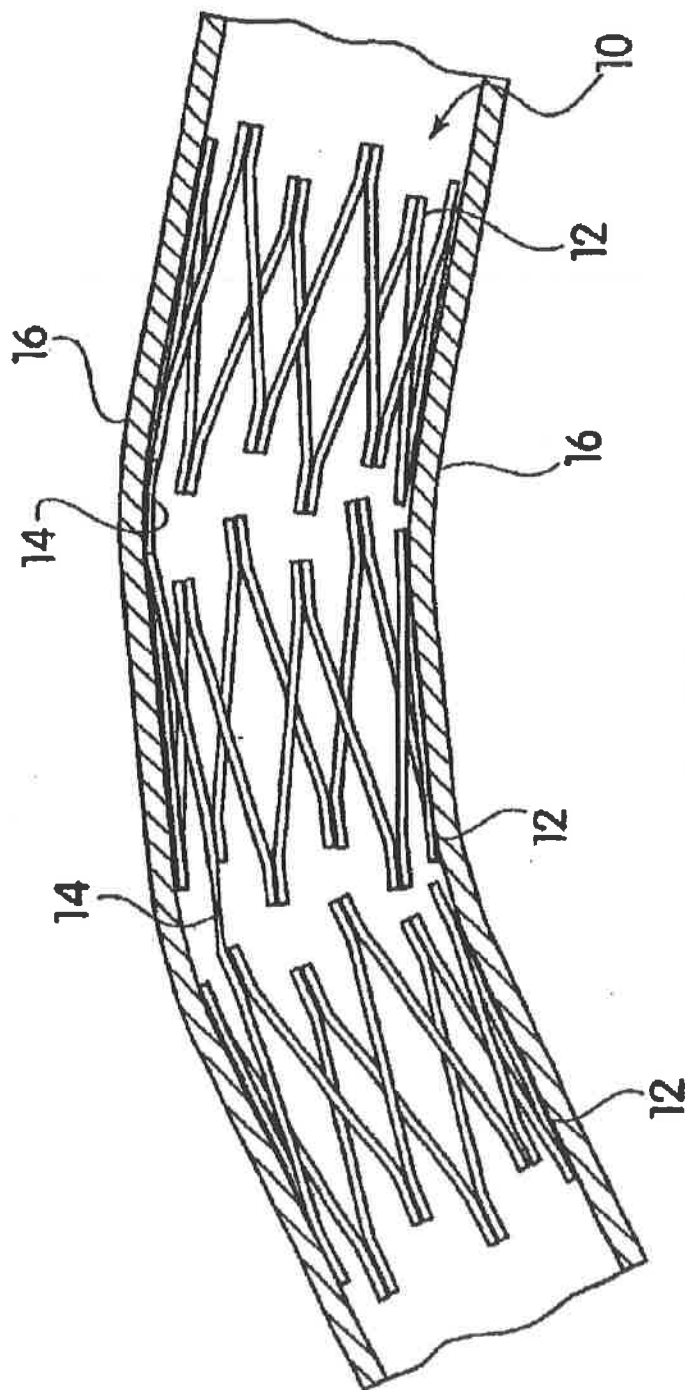


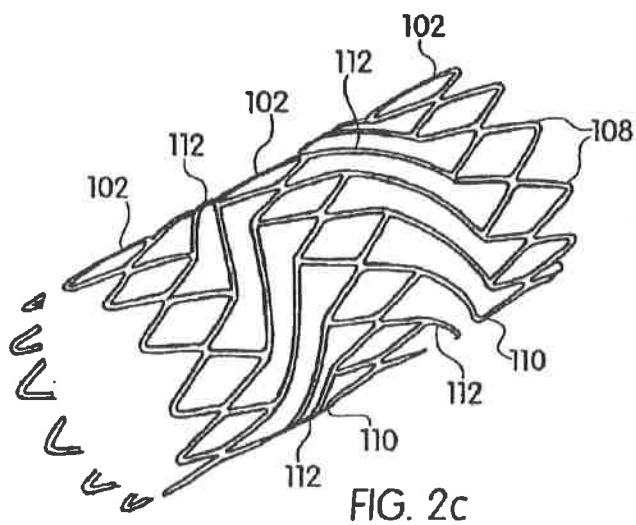
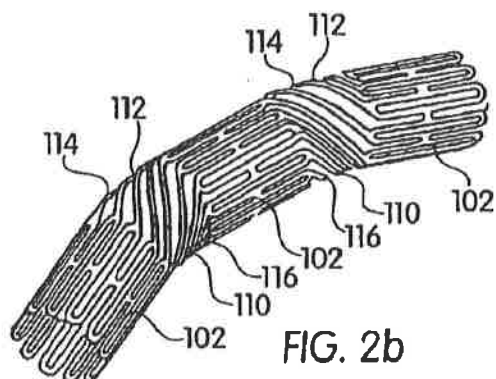
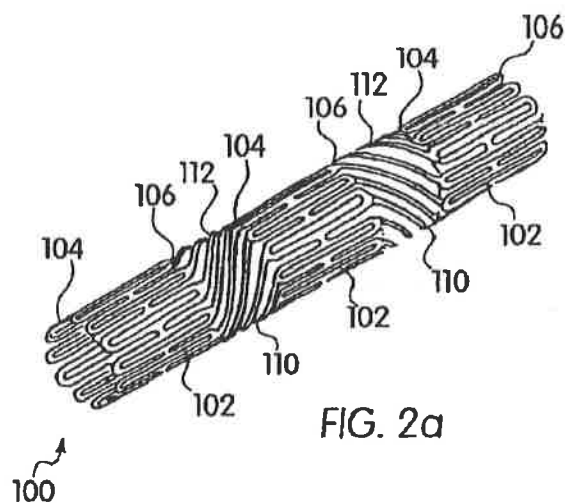
FIG. 1 (Prior Art)

U.S. Patent

Apr. 5, 2005

Sheet 2 of 5

US 6,875,228 B2

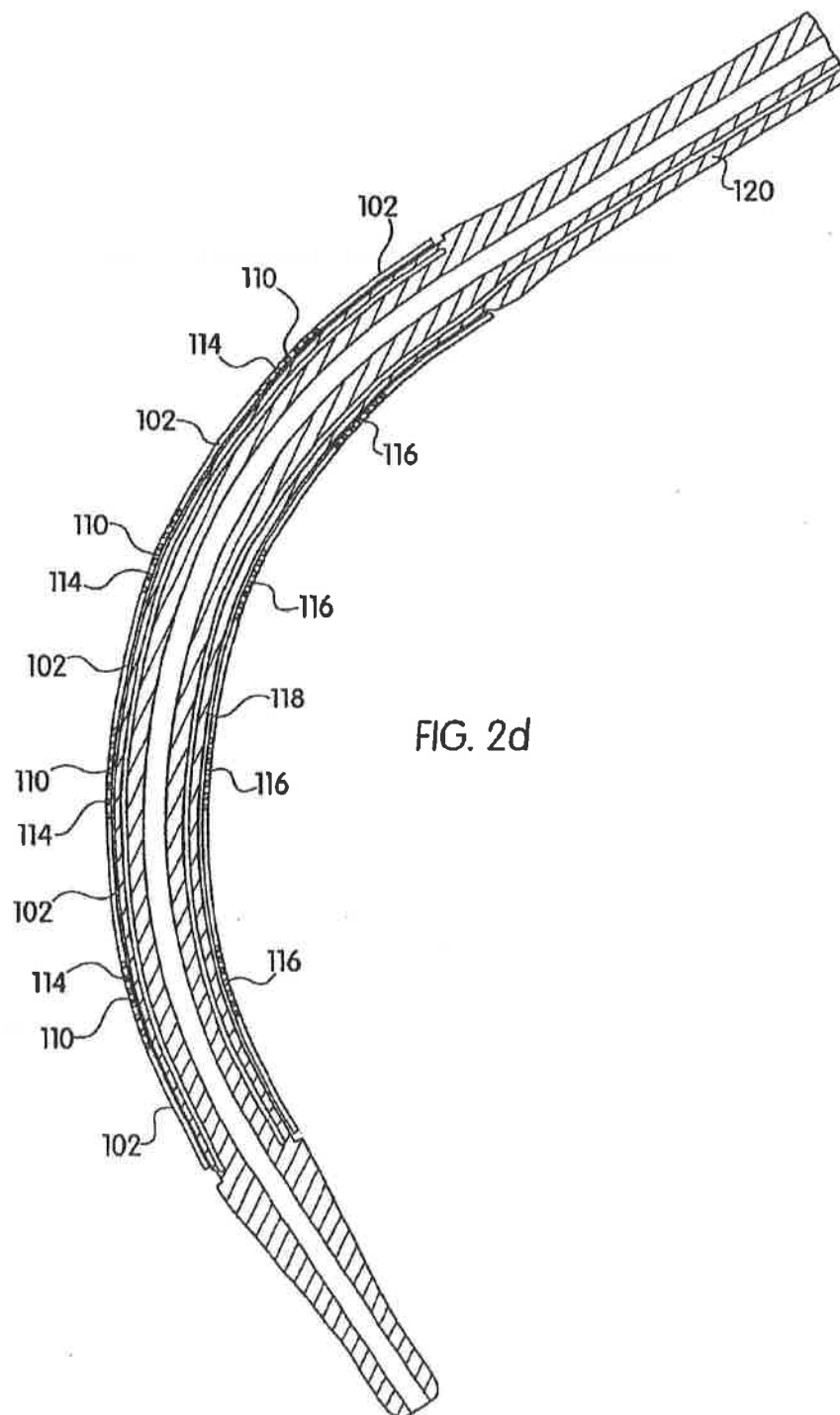


U.S. Patent

Apr. 5, 2005

Sheet 3 of 5

US 6,875,228 B2



**U.S. Patent**

Apr. 5, 2005

Sheet 4 of 5

**US 6,875,228 B2**

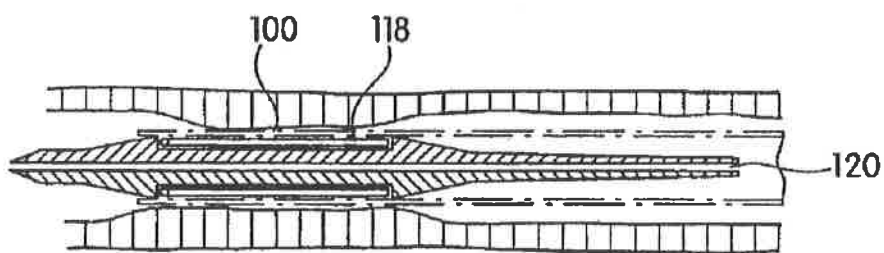


FIG. 2e

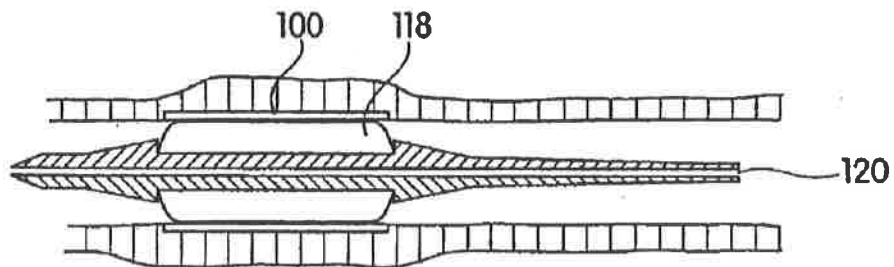


FIG. 2f

U.S. Patent

Apr. 5, 2005

Sheet 5 of 5

US 6,875,228 B2

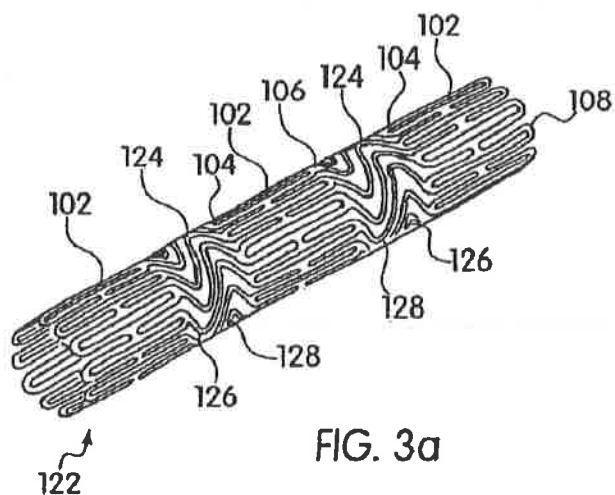


FIG. 3a

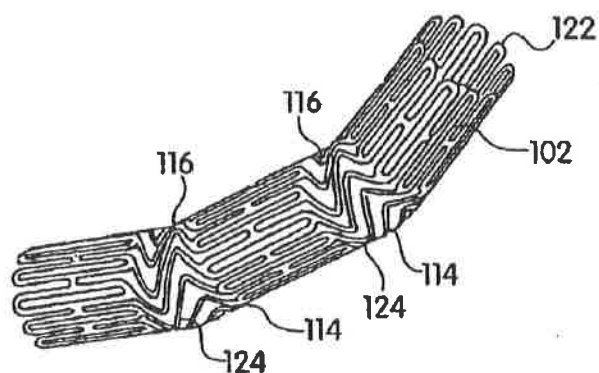


FIG. 3b

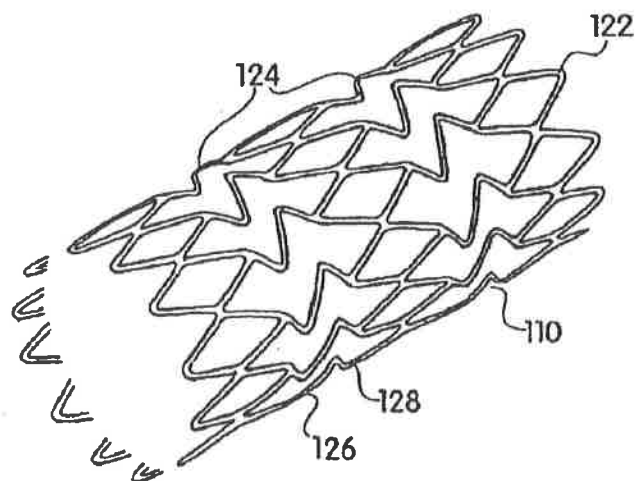


FIG. 3c



US 6,875,228 B2

1

## ARTICULATED STENT

## RELATED PATENT APPLICATIONS

This application a continuation of U.S. patent application Ser. No. 10/292,759 filed Nov. 13, 2000 now U.S. Pat. No. 6,589,276, which is a continuation of U.S. patent application Ser. No. 09/483,082 filed on Jan. 14, 2000 now U.S. Pat. No. 6,508,834, which is a continuation of U.S. patent application Ser. No. 09/026,750 filed Feb. 20, 1998 (now U.S. Pat. No. 6,059,811), which is a continuation of U.S. patent application Ser. No. 08/760,359 filed Dec. 4, 1996 (now U.S. Pat. No. 5,980,552), which is a continuation of U.S. patent application Ser. No. 08/455,462 filed May 31, 1995 (abandoned), which is a continuation of U.S. patent application Ser. No. 08/213,272 filed Mar. 17, 1994 (now U.S. Pat. No. 5,449,373).

## FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to stents which are implanted as part of a balloon angioplasty procedure within a bodily conduit of a living animal or a human to maintain patency. In particular, the present invention relates to articulated intravascular stents for delivery through or implantation in a blood vessel having a curved portion.

Intravascular stents having a constricted diameter for delivery through a blood vessel and an expanded diameter for applying a radially outwardly extending force for supporting the blood vessel are known in the art. Articulated intravascular stents for either delivery through a curved blood vessel or implanted therein are also known in the art.

Self-expandable articulated stents are described, for example, in U.S. Pat. No. 5,104,404 entitled "Articulated Stent" to Wolff. Balloon expandable articulated stents are commercially available under the trade name Palmaz-Schatz Balloon-Expandable Stents from Johnson & Johnson Intervention Systems Co.

A prior art self-expandable articulated intravascular stent 10 deployed in a curved blood vessel 16 is now described with reference to FIG. 1 which is, in actual fact, FIG. 2 of the above referenced U.S. Pat. No. 5,104,404. Stent 10 is made up of a number of individual segments 12 articulated by hinges 14 connected at each end to segments 12. Stent 10 is preferably fabricated from memory shape material, for example, nitinol, and as such is self expandable after delivery from a delivery system described in U.S. Pat. No. 4,830,003 to Wolff et al. However, these prior art articulated intravascular stents suffer from a number of disadvantages both during delivery through a curved blood vessel and when implanted therein as will now described.

The delivery of stent 10 through curved blood vessel 16 is more complicated than the delivery of a non-articulated stent in that stent 10 has to be angularly oriented such that its hinges 14 are located towards the convex portion of blood vessel 16 so that stent 10 can be flexed inward. In the present example, it will be noted that hinges 14 are located on the same side of segments 12 because blood vessel 16 has only a simple curve in one plane. It can be readily appreciated that delivery of stents through blood vessels which have one or more curved portions which are not in the same plane is even more complicated and generally requires specially constructed stents.

Even when implanted in a curved blood vessel 16, stents 10 are shown to be lacking in that the gaps between segments 12 render the curved portion of blood vessel 16

2

without support. Furthermore, the gaps at the convex portion of blood vessel 16 are substantially greater than the gaps at the concave portion thereof, thereby inducing non-uniform and therefore undesirable stresses on blood vessel 16.

Therefore, it would be highly desirable to have an articulated stent which does not require any particular angular orientation when being delivered through a curved bodily conduit and provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted.

It would also be highly desirable the structure of a stent does not depend on the particular orientations of curved portions of a blood vessel.

## SUMMARY OF THE INVENTION

The object of the present invention is for an articulated stent which can be delivered through a curved bodily conduit using a routine medical procedure and a conventional stent delivery system. Furthermore, the stent provides continuous and uniform support for both straight and curved portions of a bodily conduit when implanted. Still further, the structure of a stent and its support of a bodily conduit do not depend on the orientations of the curved portions of the conduit.

The objective of the present invention is achieved by an articulated stent, comprising: (a) at least two substantially rigid segments; and (b) a flexible connector for connecting adjacent segments, wherein the connector assumes a substantially cylindrical configuration when relaxed and a differentially stretched and compressed curved configuration when flexed.

After expansion, the rigid segments of the stent preferably present a fine diamond shaped mesh having 1 mm long sides to provide continuous and uniform support for straight portions of a bodily conduit.

The connectors can be implemented as a plurality of substantially helical links connecting adjacent segments. Alternatively, the connectors can be implemented as links each having at least one kink. The connectors typically have between 8-24 links to provide continuous and uniform support for both straight and curved portions of a bodily conduit.

The stents have constricted diameters for intraluminal delivery and are then deformed, by the inflation of a balloon forming part of their catheter delivery system, to expanded diameters for applying radially outwardly extending forces for supporting the lumen of bodily conduits. The constricted and expanded diameters of the stents typically fall in the ranges of 1.0-3.5 mm and 3.5-10.0 mm, respectively.

The stents are preferably fabricated from low memory, more plastic than elastic, bio-compatible materials, for example, stainless steel 316L, gold, tantalum, etc. which enables them to be plastically deformed from their constricted diameters to their expanded diameters.

A typical stent for implantation in a human coronary artery is 9-21 mm long comprising three to seven 2.2 mm long stent segments connected by two to six 1 mm long connectors such that the ends of the stent subtend between a 45° to 135° angle at a radius of curvature of approximately 9 mm when flexed.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings, wherein:

US 6,875,228 B2

3

FIG. 1 shows a close-up view of a prior art articulated stent of deployed in a curved blood vessel;

FIGS. 2a and 2b show a preferred embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation;

FIG. 2c shows the expanded stent of FIG. 2 after plastic deformation;

FIG. 2d shows the stent of FIG. 2 mounted on a catheter in its flexed state;

FIGS. 2e and 2f show the stent of FIG. 2 before and after expansion by a balloon forming part of its catheter delivery system;

FIGS. 3a and 3b show a second embodiment of an articulated stent, constructed and operative according to the teachings of the present invention, in its relaxed and flexed states before plastic deformation; and

FIG. 3c shows the expanded stent of FIG. 3 after plastic deformation.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is of an articulated stent for delivering through a curved bodily conduit, for example, a peripheral or coronary artery of a living animal or a human and implantation therein as part of a balloon angioplasty procedure to maintain patency.

The principles and operation of the articulated stent of the present invention may be better understood with reference to the drawings and the accompanying description.

Referring now to the drawings, FIGS. 2a-2c show an articulated stent, generally designated 100, constructed and operative according to the teachings of the present invention, generally comprising a number of substantially rigid segments 102 connected by connectors 110.

Segments 102 are preferably made up to present a fine diamond mesh of interconnected diamond shaped cells 108 having 1 mm sides on expansion as best seen in FIG. 2c. Depending on the intended diameter of stent 100, segments 102 typically comprise between 8-24 diamond shaped cells 108.

Connectors 110 comprise links 112 connecting a front end 104 to a tail end 106 of adjacent segments 102. Links 112 preferably extend in a substantially helical fashion between apexes of diamond shaped cells 108 at front and rear ends 104 and 106 of adjacent segments 102 such that the number of links 112 equals the number of cells 108. Links 112 are preferably evenly deployed around perimeters of segments 102 such that connectors 110 can be equally flexed in any direction and to provide continuous and uniform support to both straight and curved portions of a bodily conduit.

Alternate connectors 110 at front and rear ends 104 and 106, respectively, of a segment 102 preferably have links 112 wound in clockwise and counter clockwise directions. Alternately winding connectors 110 ensures that the rotational displacement of links 112 and adjacent segments 102 relative to the walls of a blood vessel and more importantly the balloon of its delivery system is minimized when stent 100 is expanded.

It is particular feature of the present invention that connectors 110 have a generally cylindrical configuration when stent 100 is relaxed as best seen in FIG. 2a and a differentially stretched and compressed curved configuration when stent 100 is flexed as best seen in FIG. 2b. The flexed configuration is brought about by two relatively opposing

4

displacements of links 112. First, the differential stretching of connectors 110 occurs at the convex portion thereof denoted 114 by links 112 being displaced away from one another. Second, the differential compressing of connectors 110 occurs at the concave portion thereof denoted 116 by links 112 being displaced towards one another.

Stent 100 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 2a and 2b and an expanded diameter as shown in FIG. 2c for supporting a bodily conduit. Stent 100 is preferably fabricated from low memory, more plastic than elastic, bio-compatible material, for example, stainless steel 316L, gold, tantalum, etc. which enables it to be plastically deformed from its constricted diameter to its expanded diameter. The constricted and expanded diameters of stent 100 typically fall in the ranges of 1.0-3.5 mm and 3.5-10.0 mm, respectively.

With reference now to FIGS. 2d-2f, stent 100 is shown overlying a balloon 118 forming part of its catheter delivery system 120. Stent 100 is mounted on its catheter delivery system 120 in its constricted diameter state shown in FIG. 2e for plastic deformation through inflation of balloon 118 to its expanded diameter shown in FIG. 2f for supporting the walls of a bodily conduit. An exemplary stent for implantation in a human coronary artery, is typically 15 mm long made up of five 2.2 mm long segments 102 connected by four 1 mm long connectors 110 and capable of flexion such that its ends subtend a 90° angle at a radius of curvature of approximately 9 mm.

The delivery of articulated stent 100 is considerably simpler than the delivery of prior art articulated stent 10 because stent 100 is equally flexible in all direction and therefore does not require a dedicated angular orientation to pass a particular curved portion. This advantage is particularly important for delivery through blood vessels having multiple curved portions. It is a further advantage of stent 100 over prior art stents 10, that stent 100 provides continuous and uniform support along the entire length of a blood vessel by means of segments 102 and unflexed connectors 110 supporting straight portions thereof while connector portions 114 and 116 supporting convex and concave curved portions thereof, respectively.

With reference now to FIGS. 3a and 3b, an articulated stent 122 is shown in which connectors 124 comprise links 126 having one or more kinks 128. The design of connectors 124 is preferred to that of connector 110 because stent 100 may have a tendency to rupture balloon 118 due to two reasons. First, links 112 overlying the convex portion of balloon 118 have a tendency to be biased inward when stent 100 is flexed. Second, segments 102 display a rotational displacement relative to balloon 118 when stent 100 is expanded.

In this case, the differentially stretched and compressed curved configuration of connector 124 is brought about by two relatively opposing displacements of links 112 as before except that the differential stretching of connectors 124 at convex portion 114 occurs by kinks 128 being somewhat straightened out while the differential compressing of connectors 124 at concave portion 116 occurs by kinks 128 being more acutely bent.

In a similar fashion to stent 100, stent 122 has a constricted diameter for delivery through a curved bodily conduit as shown in FIGS. 3a and 3b and an expanded diameter as shown in FIG. 3c for supporting a bodily conduit when implanted therein.

While the invention has been described with respect to a limited number of embodiments, it will be appreciated that

US 6,875,228 B2

5

many variations, modifications and other applications of the invention may be made.

What is claimed is:

1. An expandable stent comprising:

(a) at least two substantially longitudinally rigid segments,

(i) each of said substantially rigid segments having a plurality of U or V-shaped regions in both the expanded and unexpanded configuration, the U or V-shaped regions being more open in the expanded configuration than in the unexpanded configuration,

(ii) each of said substantially rigid segments presenting a substantially cylindrical structure defining a longitudinal passageway therethrough in both the expanded and unexpanded configurations, the cylindrical structure being shorter in length and wider in diameter in the expanded configuration than in the unexpanded configuration,

(b) a flexible connector comprising a plurality of flexible links disposed between and connecting adjacent substantially longitudinally rigid segments,

(i) each of said flexible links connecting a U or V-shaped region of a substantially rigid segment with the nearest U or V-shaped region of the adjacent substantially rigid segment,

(ii) each of said flexible links, when viewed laterally, having a first portion, a second portion and at least one area of inflection disposed between the first portion and the second portion, and

(iii) none of said flexible links projecting into said longitudinal passageway in the unexpanded configuration.

2. An expandable stent in accordance with claim 1, wherein each of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, is connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

3. An expandable stent in accordance with claim 2 wherein substantially all of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, are connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

4. An expandable stent in accordance with claim 3, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

5. An expandable stent in accordance with claim 3 wherein the average length of the flexible links, from each one's point of connection of said first portion to a substantially rigid segment to the point of connection of said second portion to a substantially rigid segment is greater in the expanded configuration than in the unexpanded configuration.

6. An expandable stent in accordance with claim 4 wherein the average length of the flexible links, from each one's point of connection of said first portion to a substantially rigid segment to the point of connection of said second portion to a substantially rigid segment is greater in the expanded configuration than in the unexpanded configuration.

7. An expandable stent in accordance with claim 2, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

8. An expandable stent in accordance with claim 7 wherein the average length of the flexible links, from each one's point of connection of said first portion to a substan-

6

tially rigid segment to the point of connection of said second portion to a substantially rigid segment is greater in the expanded configuration than in the unexpanded configuration.

9. An expandable stent in accordance with claim 2 wherein the average length of the flexible links, from each one's point of connection of said first portion to a substantially rigid segment to the point of connection of said second portion to a substantially rigid segment is greater in the expanded configuration than in the unexpanded configuration.

10. An expandable stent in accordance with claim 1, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

11. An expandable stent in accordance with claim 10 wherein the average length of the flexible links, from each one's point of connection of said first portion to a substantially rigid segment to the point of connection of said second portion to a substantially rigid segment is greater in the expanded configuration than in the unexpanded configuration.

12. An expandable stent in accordance with claim 1 wherein the average length of the flexible links, from each one's point of connection of said first portion to a substantially rigid segment to the point of connection of said second portion to a substantially rigid segment is greater in the expanded configuration than in the unexpanded configuration.

13. An expandable stent in accordance with claim 1, wherein each of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, is connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

14. An expandable stent in accordance with claim 13, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

15. An expandable stent comprising:

(a) at least two substantially longitudinally rigid segments,

(i) each of said substantially rigid segments having a plurality of U or V-shaped regions in both the expanded and unexpanded configuration, the U or V-shaped regions being more open in the expanded configuration than in the unexpanded configuration,

(ii) each of said substantially rigid segments presenting a substantially cylindrical structure defining a longitudinal passageway therethrough in both the expanded and unexpanded configurations, the cylindrical structure being shorter in length and wider in diameter in the expanded configuration than in the unexpanded configuration,

(b) a flexible connector comprising a plurality of flexible links disposed between and connecting adjacent substantially longitudinally rigid segments,

(i) each of said flexible links having end points which are aligned substantially parallel to the longitudinal axis of the stent,

(ii) each of said flexible links, when viewed laterally, having a first portion, a second portion and at least one area of inflection disposed between the first portion and the second portion, and

(iii) none of said flexible links projecting into said longitudinal passageway in the unexpanded configuration.

16. An expandable stent in accordance with claim 15, wherein each of said U or V-shaped regions, other than the



US 6,875,228 B2

7

U or V-shaped regions at the ends of the stent, is connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment.

17. An expandable stent in accordance with claim 16 wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments. 5

18. An expandable stent in accordance with claim 15, wherein substantially all of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent, are connected by a flexible link to a U or V-shaped region of the adjacent substantially rigid segment. 10

19. An expandable stent in accordance with claim 18 wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments. 15

20. An expandable stent in accordance with claim 15 wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments. 20

21. An expandable stent comprising:

(a) at least two substantially rigid segments,

(i) each of said substantially rigid segments having a plurality of U or V-shaped regions in both the expanded and unexpanded configuration, the U or V-shaped regions being more open in the expanded configuration than in the unexpanded configuration, 25

(ii) each of said substantially rigid segments presenting a substantially cylindrical structure defining a lon-

8

gitudinal passageway therethrough in both the expanded and unexpanded configurations, the cylindrical structure being wider in diameter in the expanded configuration than in the unexpanded configuration,

(b) a flexible connector comprising a plurality of flexible links disposed between and connecting adjacent substantially rigid segments,

(i) each of said flexible links connecting a U or V-shaped region of a substantially rigid segment with the nearest U or V-shaped region of the adjacent substantially rigid segment, with substantially all of said U or V-shaped regions, other than the U or V-shaped regions at the ends of the stent being connected,

(ii) each of said flexible links, when viewed laterally, having a first portion, a second portion and at least one area of inflection disposed between the first portion and the second portion, and

(iii) none of said flexible links projecting into said longitudinal passageway in the unexpanded configuration.

22. An expandable stent in accordance with claim 21, wherein said substantially rigid segments are substantially rigid particularly when compared to said flexible connectors disposed between said substantially rigid segments.

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